PB84-198647

Development Document for Effluent Limitations Guidelines and Standards for the Canmaking Subcategory of the Coil Coating Point Source Category

(U.S.) Environmental Protection Agency
Washington, DC

Apr 84

U.S. Department of Commerce
National Technical Information Service
NTIS

United States
Environmental Protection
Agency

Effluent Guidelines Division
WH-552
Washington, DC 20460

EPA 440/1-83/071
November 1983

PB84-198647

Water and Waste Management

EPA

Development Document for Effluent Limitations Guidelines and Standards for the Coil Coating

Final

Point Source Category
(Canmaking Subcategory)

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA 22161

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA 440/1-83/071	2.	3. RECIPIENT'S ACCESSION NO. PB84-198647
4. TITLE AND SUBTITLE Development Document for Effluent Limitations Guidelines and Standards for the Coil Coating Point Source Category (Canmaking Subcategory)		5. REPORT DATE April 1984
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Marl L. Belefski, Project Officer Ernst P. Hall, Branch Chief		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. EPa - Effluent Guidelines Division 401 M. Street S.W. (WH-552) Washington, D.C. 20460		10. PROGRAM ELEMENT NO.
		11. CONTRACT/GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS U.S. EPA 401 M Street S.W. (WH-552) Washington, D.C. 20460		13. TYPE OF REPORT AND PERIOD COVERED Final Report
		14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES Assistance for initial effort on this project was provided by Sverdrup & Parcel (contract 68-01-4408) and Hamilton Standard (contract 68-01-4668)

16. ABSTRACT

This document provides the technical documentation for promulgation effluent limitations and standards for the canmaking industry. The regulation covers those facilities involved in washing cans, particularly seamless two-piece cans. Effluent limitations are based on best practicable technology (BPT) and best available technology (BAT) for existing direct dischargers. Pretreatment standards for existing source (PSES) are based on best available technology. Best demonstrated technology is the based for new source performance standards (NSPS) for direct dichargers and pretreatment standards for new sources (PSNS) for indirect dischargers.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Canmaking Metal Coating and Allied Services Water Pollution Control Waste Treatment Disposal Clean Water Act		

18. DISTRIBUTION STATEMENT Release Unlimited	19. SECURITY CLASS *(This Report)* unclassied	21. NO. OF PAGES 401
	20. SECURITY CLASS *(This page)*	22. PRICE

EPA Form 2220-1 (9-73)

DEVELOPMENT DOCUMENT
for
EFFLUENT LIMITATIONS GUIDELINES AND STANDARDS
for the
CANMAKING SUBCATEGORY
# of the
COIL COATING
POINT SOURCE CATEGORY

William Ruckelshaus
Administrator

Jack E. Ravan
Assistant Administrator
Office of Water

Steven Schatzow, Director
Office of Water Regulations and Standards

Jeffery D. Denit, Director
Effluent Guidelines Division

Ernst P. Hall, P.E., Chief
Metals and Machinery Branch

Mary L. Belefski
Project Officer

April, 1984

U.S. Environmental Protection Agency
Effluent Guidelines Division
Office of Water Regulations and Standards
Washington, D.C. 20460

CONTENTS

Section		Page
I	SUMMARY AND CONCLUSIONS	1
II	RECOMMENDATIONS	7
	Existing Sources	7
	New Sources	8
	Pretreatment Standards	9
III	INTRODUCTION	11
	Legal Authority	11
	Guidelines Development Summary	11
	Description of the Canmaking Subcategory of the Coil Coating Category	14
	Industry Summary and Outlook	22
	Treatment In Place	23
IV	INDUSTRY SUBCATEGORIZATION	33
	Subcategorization Basis	33
	Production Normalizing Parameter	39
V	WATER USE AND WASTEWATER CHARACTERIZATION	41
	Information Collection	41
	Plant Data Collection	42
	Sampling Program	44
	Data Analysis	47
VI	SELECTION OF POLLUTANT PARAMETERS	87
	Pollutant Parameters	87
	Specific Pollutants Considered for Regulation	128
VII	CONTROL AND TREATMENT TECHNOLOGIES	135
	End-of-Pipe Treatment Technologies	135
	Major Technologies	136
	Chemical Reduction of Chromium	136
	Chemical Precipitation	138
	Cyanide Precipitation	144
	Granular Bed Filtration	145
	Pressure Filtration	149
	Settling	150
	Skimming	153
	Major Technology Effectiveness	157
	L&S Performance-Combined Metals Data Base	157
	LS&F Performance	171
	Analysis of Treatment System Effectiveness	172

CONTENTS

Section		Page
	Minor Technologies	175
	Flotation	175
	Chemical Emulsion Breaking	177
	Carbon Adsorption	180
	Centrifugation	182
	Coalescing	184
	Cyanide Oxidation by Chlorine	186
	Cyanide Oxidation by Ozone	187
	Cyanide Oxidation by Ozone and U.V. Radiation	188
	Cyanide Oxidation by Hydrogen Peroxide	189
	Evaporation	190
	Gravity Sludge Thickening	193
	Insoluble Starch Xanthate	194
	Ion Exchange	194
	Membrane Filtration	197
	Peat Adsorption	199
	Reverse Osmosis	200
	Sludge Bed Drying	203
	Ultrafiltration	205
	Vacuum Filtration	208
	In-Plant Technologies	209
	Canwasher Configuration	209
	Countercurrent Cascade Rinsing	211
	Equipment Maintenance	213
	In-Process Control	213
	In-Process Substitutions	214
VIII	COST OF WASTEWATER CONTROL AND TREATMENT	269
	Changes in Costs Between Proposal and Promulgation	269
	Cost Estimation Methodology	270
	General Cost Factors	272
	Technology Basis for Cost Estimation	274
	System Cost Development	284
	Nonwater Quality Environmental Aspects	285
IX	BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE	311
	Technical Approach to BPT	311
	Selection of Pollutant Parameters for Regulation	313
	Canmaking Subcategory BPT	313

CONTENTS

Section		Page
X	BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE	325
	Technical Approach to BAT	325
	BAT Option Selection	326
	Regulated Pollutant Parameters	327
	Canmaking Subcategory BAT	329
	Demonstration Status	330
XI	NEW SOURCE PERFORMANCE STANDARDS	341
	Technical Approach to NSPS	341
	NSPS Option Selection	342
	Regulated Pollutant Parameters	343
	Canmaking Subcategory NSPS	344
	Demonstration Status	346
XII	PRETREATMENT STANDARDS	353
	Pretreatment Standards	356
	Demonstration Status	357
XIII	BEST CONVENTIONAL POLLUTANT CONTROL TECHNOLOGY	363
XIV	ACKNOWLEDGMENTS	365
XV	REFERENCES	367
XVI	GLOSSARY	377
	Oil and Grease Analytical Method	390
	Conversion Factors	392

TABLES

Number	Title	Page
V-1	Dcp Priority Pollutant Responses	53
V-2	Water Use Data for Canmaking Plants, Aluminum Basis Material	54
V-3	Water Use Data for Canmaking Plants, Steel Basis Material	55
V-4	Visited or Sampled Canmaking Plants	56
V-5	Sampled Plant Water Use	57
V-6	Water Use Data Provided by CMI & USBA	58
V-7	Summary of Water Use (1/1000 cans)	59
V-8	Sampling Analysis Results - Raw Wastewater (mg/l)	60
V-9	CMI & USBA Sampled Plants Raw Wastewater Data (mg/l)	62
V-10	Postproposal EPA Sampling Analysis Results Raw Wastewater (mg/l)	64
V-11	Statistical Analysis Raw Wastewater Pollutants (mg/l) Aluminum Basis Material	65
V-12	Statistical Analysis - CMI & USBA Raw Wastewater Data (mg/l) Aluminum Basis Material	67
V-13	Treatment in Place	68
V-14	Dcp Effluent Data (mg/l)	71
V-15	Sampled Plants Effluent Data (mg/l) Aluminum Basis Material	76
V-16	Sampled Plants Effluent Data (mg/1000 cans) Aluminum Basis Material	78
V-17	CMI & USBA Effluent Data (mg/l)	80
V-18	CMI & USBA Effluent Data (mg/1000 cans)	82

TABLES

Number	Title	Page
V-19	Postproposal EPA Sampled Plants Effluent Data (mg/l)	84
V-20	Postproposal EPA Sampled Plants Effluent Data (mg/1000 cans)	85
V-21	Reynolds Aluminum Company Effluent Data (mg/l)	86
VI-1	Priority Pollutant Disposition	133
VII-1	pH Control Effect on Metals Removal	216
VII-2	Effectiveness of Sodium Hydroxide for Metals Removal	216
VII-3	Effectiveness of Lime and Sodium Hydroxide for Metals Removal	217
VII-4	Theoretical Solubilities of Hydroxides and Sulfides of Selected Metals in Pure Water	217
VII-5	Sampling Data from Sulfide Precipitation - Sedimentation Systems	218
VII-6	Sulfide Precipitation - Sedimentation	219
VII-7	Ferrite Co-precipitation Performance	220
VII-8	Concentration of Total Cyanide	220
VII-9	Multimedia Filter Performance	221
VII-10	Performance of Selected Settling Systems	221
VII-11	Skimming Performance	222
VII-12	Selected Partition Coefficients	223
VII-13	Trace Organic Removal by Skimming	224
VII-14	Combined Metals Data Effluent Values (mg/l)	224
VII-15	L&S Performance, Additional Pollutants	225
VII-16	Combined Metals Data Set - Untreated Wastewater	225

TABLES

Number	Title	Page
VII-17	Maximum Pollutant Level in Untreated Wastewater, Additional Pollutants	226
VII-18	Precipitation - Settling - Filtration (LS&F) Performance, Plant A	227
VII-19	Precipitation - Settling - Filtration (LS&F) Performance, Plant B	228
VII-20	Precipitation - Settling - Filtration (LS&F) Performance, Plant C	229
VII-21	Summary of Treatment Effectiveness	230
VII-22	Treatability Rating of Priority Pollutants Utilizing Carbon Adsorption	231
VII-23	Classes of Organic Compounds Adsorbed on Carbon	232
VII-24	Activated Carbon Performance (Mercury)	233
VII-25	Ion Exchange Performance	233
VII-26	Membrane Filtration System Effluent	234
VII-27	Peat Adsorption Performance	234
VII-28	Ultrafiltration Performance	234
VII-29	Removal of Toxic Organics by Oil Removal	235
VII-30	Chemical Emulsion Breaking Efficiencies	236
VIII-1	Wastewater Sampling Frequency	288
VIII-2	Nonwater Quality Aspects of Wastewater Treatment	289
VIII-3	Nonwater Quality Aspects of Sludge and Solids Handling	290
IX-1	BPT Effluent Limitations - Canmaking Subcategory	322
X-1	Summary of Total Treatment Effectiveness - Canmaking Subcategory (BPT, BAT & PSES)	331

TABLES

Number	Title	Page
X-2	Pollutant Reduction Benefits of Control Systems - Normal Plant	332
X-3	Pollutant Reduction Benefits of Control Systems - Total Subcategory	333
X-4	Pollutant Reduction Benefits of Control Systems - Direct Dischargers	334
X-5	Treatment Costs	335
X-6	BAT Effluent Limitations, Canmaking Subcategory	336
XI-1	Summary of Treatment Effectiveness - Canmaking Subcategory (New Sources)	347
XI-2	Pollutant Reduction Benefits of Control Systems - Normal Plant (New Sources)	348
XI-3	New Source Performance Standards - Canmaking Subcategory	349
XII-1	POTW Removals of the Priority Pollutants Found in Canmaking Wastewater	358
XII-2	Toxic Organics Comprising TTO	359
XII-3	Pollutant Reduction Benefits of Control Systems - Indirect Dischargers	360
XII-4	Pretreatment Standards for Existing Sources, Canmaking Subcategory	361
XII-5	Pretreatment Standards for New Sources, Canmaking Subcategory	362

FIGURES

Number	Title	Page
III-1	Production of Draw and Iron Can Bodies	24
III-2	Detail of Can Drawing and Ironing	25
III-3	Simple Rinse Stage	26
III-4	Simple Rinse Stage with Inlet Water to Last Riser	27
III-5	Countercurrent Cascade Rinse Stage	28
III-6	Six Stage Canwasher - Simple Water Use	29
III-7	Six Stage Canwasher - Simple Counterflow Rinse	30
III-8	Six Stage Canwasher - Complete Counterflow Rinse with last Riser Introduction	31
III-9	Extended Multistage Canwasher	32
VII-1	Comparative Solubilities of Metal Hydroxides and Sulfides as a Function of pH	237
VII-2	Lead Solubility in Three Alkalies	238
VII-3	Effluent Zinc Concentration Versus Minimum Effluent pH	239
VII-4	Hydroxide Precipitation Sedimentation Effectiveness, Cadmium	240
VII-5	Hydroxide Precipitation Sedimentation Effectiveness, Chromium	241
VII-6	Hydroxide Precipitation Sedimentation Effectiveness, Copper	242
VII-7	Hydroxide Precipitation Sedimentation Effectiveness, Lead	243
VII-8	Hydroxide Precipitation Sedimentation Effectiveness, Nickel and Aluminum	244
VII-9	Hydroxide Precipitation Sedimentation Effectiveness, Zinc	245

FIGURES

Number	Title	Page
VII-10	Hydroxide Precipitation Sedimentation Effectiveness, Iron	246
VII-11	Hydroxide Precipitation Sedimentation Effectiveness, Manganese	247
VII-12	Hydroxide Precipitation Sedimentation Effectiveness, TSS	248
VII-13	Hexavalent Chromium Reduction with Sulfur Dioxide	249
VII-14	Granular Bed Filtration	250
VII-15	Pressure Filtration	251
VII-16	Representative Types of Sedimentation	252
VII-17	Activated Carbon Adsorption Column	253
VII-18	Centrifugation	254
VII-19	Treatment of Cyanide Waste by Alkaline Chlorination	255
VII-20	Typical Ozone Plant for Waste Treatment	256
VII-21	UV - Ozonation	257
VII-22	Types of Evaporation Equipment	258
VII-23	Dissolved Air Flotation	259
VII-24	Gravity Thickening	260
VII-25	Ion Exchange with Regeneration	261
VII-26	Simplified Reverse Osmosis Schematic	262
VII-27	Reverse Osmosis Membrane Configurations	263
VII-28	Sludge Drying Bed	264
VII-29	Simplified Ultrafiltration Flow Schematic	265

FIGURES

Number	Title	Page
VII-30	Vacuum Filtration	266
VII-31	Flow Diagram for Emulsion Breaking with Chemicals	267
VIII-1	General Logic Diagram of Computer Cost Model	291
VIII-2	Logic Diagram of Module Design Procedure	292
VIII-3	Logic Diagram of the Costing Routine	293
VIII-4	Costs for Spray Rinsing	294
VIII-5	Costs for Chromium Reduction	295
VIII-6	Costs for Equalization	296
VIII-7	Costs for Chemical Emulsion Breaking	297
VIII-8	Costs for Dissolved Air Flotation	298
VIII-9	Costs for Chemical Precipitation and Sedimentation	299
VIII-10	Costs for Multimedia Filtration	300
VIII-11	Costs for Ultrafiltration	301
VIII-12	Costs for Vacuum Filtration	302
VIII-13	Diagram of an Electrodialysis Unit	303
VIII-14	Capital Costs of Electrodialysis	304
VIII-15	Annual Costs of Electrodialysis	305
VIII-16	Costs for Contract Hauling	306
VIII-17	Total Capital Costs for Model Canmaking Plants - Option A (BPT)	307
VIII-18	Total Annual Costs for Model Canmaking Plants - Option A (BPT)	308
VIII-19	Total Capital Costs for Model Canmaking Plants - Option B (BAT and PSES)	309

FIGURES

Number	Title	Page
VIII-20	Total Annual Costs for Model Canmaking Plants - Option B (BAT and PSES)	310
IX-1	BPT Wastewater Treatment System	323
IX-2	All Usable Production Normalized Flow Data	324
X-1	BAT Level 1 Wastewater Treatment System	337
X-2	BAT Level 2 Wastewater Treatment System	338
X-3	BAT Level 3 Wastewater Treatment System	339
X-4	Production Normalized Flow Data for Plants Utilizing Counterflow Rinsing	340
XI-1	NSPS Level 4 Wastewater Treatment System	350
XI-2	NSPS Level 5 Wastewater Treatment System	351

SECTION I

SUMMARY AND CONCLUSIONS

Pursuant to Sections 301, 304, 306, 307, 308, and 501 of the Clean Water Act and the provisions of the Settlement Agreement in Natural Resources Defense Council v. EPA, 8 ERC 2120 (D.D.C. 1976) modified, 12 ERC 1833 (D.D.C. 1979), EPA has collected and analyzed data for plants in the Canmaking Subcategory of the Coil Coating Point Source Category. There are no existing national effluent limitations or standards for canmaking. This document and the administrative record provide the technical basis for promulgating effluent limitations based on best practicable technology (BPT) and best available technology (BAT) for existing direct dischargers, pretreatment standards for existing indirect dischargers (PSES), pretreatment standards for new indirect dischargers (PSNS), and standards of performance for new source direct dischargers (NSPS). The regulation of canmaking is included in the coil coating category because the materials processed, processes used, and wastewater characteristics are generally similar to those in coil coating.

Canmaking covers all of the manufacturing processes and steps involved in the manufacturing of various, shaped metal containers which are subsequently used for storing foods, beverages and other products. Two major types of cans, seamed and seamless, are manufactured. Seamed or three-piece cans are manufactured from flat metal, rolled and seamed to form the can body with one or two ends added. Seamless cans are drawn, redrawn, or extruded with a top or very rarely, two ends added. The common vegetable can is the classic example of a three-piece can and the aluminum beverage can is the classic example of a seamless can.

Subcategorization

The subcategory was studied for further subcategorization. In the manufacture of seamless cans, oil is used frequently as a lubricant during the forming of the seamless body and must be removed before further processing can be performed. Typically, this is accomplished by washing the can body in a continuous canwasher using water-based cleaners. This step is followed by metal surface treating steps to prepare the can for painting.

In the manufacture of seamed (welded, clinched or soldered) cans, can ends, can tops and seamless cans from coated (e.g., coil coated) stock, no oil is used and the cans do not need to be washed after forming. Because no process wastewater is generated from these canmaking process segments they are excluded from regulation.

After studying all of the processes used in canmaking, EPA determined that no further subcategorization of canmaking is required, and a single set of regulatory numbers is appropriate for all wastewater generating canmaking facilities. The production normalizing parameter is the number of cans manufactured.

Data

Data collection for this subcategory focused on wet processes associated with canmaking. The technical data base includes information from 21 companies representing about 100 manufacturing sites. In addition to the data collection effort for this study, supplemental data were obtained from NPDES permit files and engineering studies on treatment technologies used in this and other categories with similar wastewater characteristics.

Pollutants or pollutant parameters generated in canmaking wastewaters are (1) toxic metals -- chromium, copper, nickel and zinc; (2) toxic organics listed as total toxic organics (TTO) (TTO is the sum of all toxic organic compounds detected at quantifiable levels) (3) nonconventional pollutants -- aluminum, fluoride, manganese and phosphorus; and (4) conventional pollutants -- oil and grease, TSS, and pH. Because of the toxic metals present, the sludges generated during wastewater treatment generally contain toxic metals but are not regarded as toxic under RCRA when generated by the lime and settle model technology.

EPA identified both actual and potential control and treatment technologies (including in-process and end-of-process technologies). The Agency analyzed historical and newly generated data on the performance, operational limitations, and reliability of these technologies. Current wastewater treatment systems in the subcategory range from no treatment to sophisticated physical-chemical treatment combined with water conservation practices. EPA considered the impacts of these technologies on air quality, solid waste generation, water scarcity, and energy requirements.

Treatment In Place

Eighty-six plants generate wastewater from the manufacture of cans and 83 discharge directly or indirectly to waters of the United States. No treatment equipment was reported in place at 8 canmaking plants. Oil removal equipment for skimming, chemical emulsion breaking, dissolved air flotation or a combination of these is in place at 38 canmaking plants, 3 plants have chromium reduction systems, 26 canmaking plants have pH adjustment systems without settling, 23 plants indicate they have equipment for chemical precipitation and settling, 3 plants have polishing filtration equipment in place, 4 plants have ultrafiltration - one on the total plant wastewater flow, and 1 plant has reverse osmosis equipment in place.

The performance of the treatment systems in place at all canmaking plants is difficult to assess because EPA has received a limited amount of canmaking effluent data. Additionally, some plants have equipment in place which they are not operating because existing requirements can be achieved without operation of treatment equipment. Consequently, treatment performance is transferred from other categories and subcategories which treat similar wastewaters.

For the subcategory, in general, there is no significant difference between the pollutants generated by the 3 direct or 80 indirect dischargers or in the degree of treatment employed; several indirect dischargers have the same treatment equipment in-place as the direct dischargers. The degree of treatment equipment operation is primarily dependent upon the existing requirements. Section V of this document further evaluates the treatment systems in place and the influent and effluent data available.

Treatment Costs

The Agency estimated the costs of each control and treatment technology using a computer program based on standard engineering cost analysis. Unit process costs were derived by applying canmaking data and characteristics to each treatment process (i.e., metals precipitation, sedimentation, mixed-media filtration, etc.). Costs were developed for model plants having a range of wastewater flows and individual compliance costs were estimated for each plant based on the can production of the plant and treatment equipment in place; individual plant costs were summed to develop total costs for the subcategory. The Agency then evaluated the economic impacts of these costs.

Regulation

On the basis of these factors, EPA identified and classified various control and treatment technologies as BPT, BAT, NSPS, PSES, and PSNS. The regulation, however, does not require the installation of any particular technology. Rather, it requires achievement of quantitative effluent limitations and standards which can be achieved by the proper operation of these or equivalent technologies.

Except for pH requirements, the effluent limitations for BPT, BAT, NSPS, PSES and PSNS, are expressed as mass limitations -- a mass of pollutant per unit of production (number of cans). They were calculated by combining three figures: (1) treated effluent concentrations determined by analyzing control technology performance data; (2) production-weighted wastewater flow for the subcategory; and (3) any relevant process or treatment variability. This basic calculation was performed for each regulated pollutant or pollutant parameter in the subcategory.

Because flow reduction is a significant pollutant reduction technology for this subcategory, mass based limitations and standards are necessary to ensure application and implementation of the model or equivalent technology. Pretreatment standards -- PSES and PSNS-- are also expressed as mass limitations rather than concentration limits to ensure that the effluent reduction in the total quantity of pollutants discharged resulting from the model treatment technology, which includes flow reduction, is realized.

The end-of-pipe treatment technology available for this subcategory and used as the basis for the regulation includes in-process water use reduction, and end-of-pipe technologies: oil removal by skimming, dissolved air flotation, emulsion breaking, or a combination of these technologies; chromium reduction when necessary; and lime and settle technology to remove other pollutants.

BPT - The BPT limitations are based on wastewater flow normalization, chromium reduction when required, oil removal, and lime and settle treatment. The more significant pollutants found in the wastewaters of the canmaking subcategory and regulated under BPT include chromium, zinc, aluminum, fluoride, phosphorus, oil and grease, TSS, and pH. Sections VII and IX of this document explain the derivation of treatment effectiveness data and the calculation of BPT limitations based on wastewater flow normalization and oil removal plus end-of-pipe lime and settle treatment. Flow normalization is based on the normalized wastewater flow of the median plant in the subcategory. The BPT regulatory flow basis is 215 l/1000 cans.

Compliance with BPT limitations will result in direct dischargers removing (from raw waste) 2,234 kg/yr (4,925 lb/yr) of toxic pollutants and 3.79 million kg/yr (8.36 million lb/yr) of other pollutants (above raw waste) including 3.71 million kg/yr (8.18 million lb/yr) of conventional pollutants at a a capital cost (above equipment in place) (1982 dollars) of $0.743 million and a total annual cost of $0.645 million including interest and depreciation.

BAT - The BAT limitations are based on the BPT end-of-pipe treatment (chromium reduction when required, oil removal and lime and settle end-of-pipe treatment) with the addition of in-process flow reduction to reduce the discharge of toxic pollutants to the environment. The principal in-process water reduction technology is the use of counterflow rinsing in the canwasher. This technology is expected to reduce the total discharge flow by 60 percent of the BPT flow.

Six plants presently meet the BAT flow basis and 12 plants have the BAT flow technology in place. Implementation of these BAT limitations will remove an estimated 2,369 kg/yr (5,223 lb/yr) of toxic pollutants and 3.80 million kg/yr (8.38 million lb/yr) of other pollutants (above raw waste) including 3.72 million kg/yr (8.20 million lb/yr) of conventional pollutants at a capital cost above equipment in place of $0.646 million and a total annual cost of $0.594 million. These costs assume that industry will install BAT technology equipment rather than installing BPT and upgrading it to BAT. The incremental effluent reduction benefits of BAT above BPT are the removal annually of 135 kg (298 lb) of toxic pollutants and 12,000 kg (26,455 lb) of other pollutants.

The pollutants regulated under BAT include chromium, zinc, aluminum, fluoride, and phosphorus.

NSPS - The NSPS are based on the BPT end-of-pipe treatment technology and flow reduction to the level of the best plant in the subcategory achieved by the installation of counterflow rinsing in the canwasher. This reduces total discharge flow by 75 percent when compared to present raw waste. Assuming a new normal plant produces 696 million cans per year, the investment costs for compliance with this regulation would be $0.49 million and annual costs would be $0.30 million. Pollutant removals would be 797 kg/yr (1,757 lb/yr) for toxics and 1.27 million kg/yr (2.80 million lb/yr) for other pollutants from raw waste.

The pollutants regulated under NSPS include chromium, zinc, aluminum, fluoride, phosphorus, oil and grease, TSS, and pH.

PSES - The model PSES technology is equivalent to BAT. Implementation of PSES will remove an estimated 63,200 kg/yr of toxic pollutants and 100 million kg/yr of other pollutants (from raw waste) at a capital cost of $21.29 million and a total annual cost of $17.13 million.

The pollutants regulated in the canmaking subcategory under PSES include chromium, copper, zinc, fluoride, manganese, phosphorus and Total Toxic Organics (TTO). As discussed in Section V, there are toxic organics associated with lubricants, solvents and surface coatings used in the canmaking subcategory. Given the mix of toxic organic pollutants found in these wastestreams, and the fact that they may pass through POTW, the Agency is promulgating a pretreatment standard for TTO to control these pollutants. The TTO standard is based on the application of oil and grease removal technology which achieves an estimated 97 percent removal of TTO.

PSNS - The PSNS are based on the same treatment technology as NSPS. The pollutants regulated under PSNS include chromium, copper, zinc, fluoride, manganese, phosphorus, and TTO. Costs and removals are the same for a new indirect discharge source as for a new direct discharge source.

SECTION II

RECOMMENDATIONS

1. EPA has added a fourth subcategory to the coil coating category for the purpose of effluent limitations and standards. The fourth subcategory is: Canmaking.

2. The following effluent limitations are promulgated for existing sources:

Subcategory D - Canmaking

(a) BPT Limitations

Pollutant or Pollutant Property	BPT Effluent Limitations Maximum for any one day		Maximum for monthly average	
	g (lbs)/1,000,000 cans manufactured			
Chromium	94.60	(0.209)	38.70	(0.085)
Zinc	313.90	(0.692)	131.15	(0.289)
Aluminum	1382.45	(3.048)	688.00	(1.517)
Fluoride	12792.50	(28.202)	5676.00	(12.513)
Phosphorus	3590.50	(7.916)	1468.45	(3.237)
Oil & Grease	4300.00	(9.480)	2580.00	(5.688)
TSS	8815.00	(19.434)	4192.50	(9.243)
pH	within the range of 7.0 to 10 at all times			

(b) BAT Limitations

Pollutant or Pollutant Property	BAT Effluent Limitations			
	Maximum for any one day		Maximum for monthly average	
	g (lbs)/1,000,000 cans manufactured			
Chromium	36.92	(0.081)	15.10	(0.033)
Zinc	122.49	(0.270)	51.18	(0.113)
Aluminum	539.48	(1.189)	268.48	(0.592)
Fluoride	4992.05	(11.001)	2214.96	(4.883)
Phosphorus	1401.13	(3.089)	573.04	(1.263)

3. The following effluent standards are promulgated for new sources:

Subcategory D - Canmaking

New Source Performance Standards

Pollutant or Pollutant Property	NSPS			
	Maximum for any one day		Maximum for monthly average	
	g (lbs)/1,000,000 cans manufactured			
Chromium	27.98	(0.062)	11.45	(0.025)
Zinc	92.86	(0.205)	38.80	(0.086)
Aluminum	408.95	(0.902)	203.52	(0.449)
Fluoride	3784.20	(8.343)	1679.04	(3.702)
Phosphorus	1062.12	(2.342)	434.39	(0.958)
Oil & Grease	1272.00	(2.804)	763.20	(1.683)
TSS	2607.60	(5.749)	1240.20	(2.734)
pH	within the range of 7.0 to 10 at all times			

4. The following pretreatment standards are promulgated for existing sources and new sources:

(a) Pretreatment Standards for Existing Sources

	PSES			
Pollutant or Pollutant Property	Maximum for any one day		Maximum for monthly average	
	g (lbs)/1,000,000 cans manufactured			
Chromium	36.92	(0.081)	15.10	(0.033)
Copper	159.41	(0.351)	83.90	(0.185)
Zinc	122.49	(0.270)	15.18	(0.113)
Fluoride	4992.05	(11.001)	2214.96	(4.883)
Phosphorus	1401.13	(3.089)	573.04	(1.263)
Manganese	57.05	(0.126)	24.33	(0.053)
TTO	26.85	(0.059)	12.59	(0.028)
Oil & Grease (for alternate monitoring)	1678.00	(3.699)	1006.80	(2.220)

(b) Pretreatment Standards for New Sources

	PSNS			
Pollutant or Pollutant Property	Maximum for any one day		Maximum for monthly average	
	g (lbs)/1,000,000 cans manufactured			
Chromium	27.98	(0.062)	11.45	(0.025)
Copper	120.84	(0.267)	63.60	(0.140)
Zinc	92.86	(0.205)	38.80	(0.086)
Fluoride	3784.20	(8.345)	1679.04	(3.702)
Phosphorus	1062.12	(2.342)	434.39	(0.958)
Manganese	43.25	(0.095)	18.44	(0.041)
TTO	20.35	(0.045)	9.54	(0.021)
Oil & Grease (for alternate monitoring)	1272.00	(2.804)	763.20	(1.683)

SECTION III

INTRODUCTION

LEGAL AUTHORITY

The Federal Water Pollution Control Act Amendments of 1972 established a comprehensive program to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters" (Section 101(a)). To implement the Act, EPA was to issue effluent limitations, pretreatment standards, and new source performance standards for industry dischargers.

The Act included a timetable for issuing these standards. However, EPA was unable to meet many of the deadlines and, as a result, in 1976, it was sued by several environmental groups. In settling this lawsuit, EPA and the plaintiffs executed a court-approved "Settlement Agreement". This Agreement required EPA to develop a program and adhere to a schedule in promulgating effluent limitations guidelines, new source performance standards and pretreatment standards for 65 "priority" pollutants and classes of pollutants, for 21 major industries. See Natural Resources Defense Council, Inc. v. EPA, 8 ERC 2120 (D.D.C. 1976), modified, 12 ERC 1833 (D.D.C. 1979) modified by orders dated August 25 and October 26, 1982 and August 2, 1983.

Many of the basic elements of this Settlement Agreement program were incorporated into the Clean Water Act of 1977. Like the Agreement, the Act stressed control of toxic pollutants, including the 65 "priority" pollutants. In addition, to strengthening the toxic control program, Section 304(e) of the Act authorizes the Administrator to prescribe "best management practices" (BMP) to prevent the release of toxic and hazardous pollutants from plant site runoff, spillage or leaks, sludge or waste disposal, and drainage from raw material storage associated with, or ancillary to, the manufacturing or treatment process.

GUIDELINES DEVELOPMENT SUMMARY

These effluent limitations and standards were developed from data obtained from previous EPA studies, literature searches, and a plant survey and evaluation program. This program was carried out in 1978-79 with follow-up work done in 1982. Additional data and information was collected after proposal in 1983. This information was then catalogued in the form of individual plant summaries describing processes performed, production rates, raw

Preceding page blank

materials utilized, wastewater treatment practices, water use and wastewater characteristics.

In addition to providing a quantitative description of the canmaking subcategory, this information was used to determine if the characteristics of the subcategory as a whole were uniform and thus amenable to one set of effluent limitations and standards. The characteristics of the plants, manufacturing processes, and process wastewater generation and discharge were evaluated to determine whether additional subcategories were necessary. The subcategorization process is discussed in Section IV.

To supplement existing data, the Agency sent a data collection portfolio (dcp) under authority of Section 308 of the Federal Water Pollution Control Act, as amended, to each known canmaking company. Additional data were obtained through a sampling program carried out at selected sites; sampling was conducted at 5 plants before proposal. After proposal, engineering visits were made to 17 plants and short term samples taken at 7 plants. The designated priority pollutants (65 toxic pollutants) and typical canmaking pollutants formed the basic list for chemical analysis. Sampling and analysis were conducted to determine the source and quantity of the pollutant parameters.

EPA analyzed the available data to determine wastewater generation and mass discharge rates in terms of production. In addition to evaluating pollutant generation and discharges, the Agency identified the full range of control and treatment technologies existing within or applicable to the canmaking subcategory. This was done considering the pollutants to be treated and the chemical, physical and biological characteristics of the pollutants. Special attention was paid to in-process technology such as the recovery and reuse of process solutions, the recycle of process water and the curtailment of water use.

Consideration of these factors enabled EPA to characterize various levels of technology as the basis for effluent limitations for existing sources based on BPT and BAT. Levels of technology appropriate for pretreatment of wastewater introduced into a POTW from both new and existing sources were also identified, as were the NSPS based on best demonstrated control technology processes, operating methods, or other alternatives (BDT) for the control of direct discharges from new sources. These technologies were considered in terms of demonstrated performance, pretreatment requirements, the total cost of application of the technology, the age of equipment and facilities involved, the processes employed, the engineering aspects of applying various types of control technique process changes, and nonwater quality environmental impacts (including energy requirements).

Sources of Industry Data

Data on the canmaking subcategory were gathered from EPA studies, literature studies, inquiries to federal and state environmental agencies, raw material manufacturers and suppliers, trade association contacts and the canmaking manufacturers. Additionally, meetings were held with industry representatives and the EPA. Known canmakers were sent a data collection portfolio (dcp) requesting specific information concerning each facility. Following proposal, additional information was also collected to clarify comments. Finally, a sampling program was carried out at 5 plants before proposal and at 7 plants following proposal. The sampling program consisted of sampling and analysis at each facility to determine the presence of a broad range of pollutants and to quantify the pollutants present in canmaking wastewater. Specific details of the sampling program and information from the above data sources are presented in Section V.

Literature Study - Published literature in the form of books, reports, papers, periodicals, and promotional materials was examined. The more informative sources are listed in Section XV.

Plant Survey and Evaluation - The collection of data pertaining to canmaking facilities was a two-phased operation. First, EPA mailed a dcp to each company in the country known or believed to perform canmaking. This dcp included sections for general plant data, specific production process data, wastewater management process data, raw and treated wastewater data, wastewater treatment cost information, and priority pollutant information based on 1977 production records. Second, follow-up dcps were sent and returned with information based on 1981 production records. From this mailing and other contact with the industry, it is estimated that there are about 425 canmaking plants. The data base includes specific information from 21 companies representing about 100 manufacturing sites and general information from the industry trade association. However, plants manufacturing certain types of cans and can tops or ends discharge no process wastewater. The EPA data base contains information about 86 canmaking plants that wash cans, 83 of which discharge process wastewater and are subject to this regulation.

Utilization of Industry Data

Data collected from the previously listed sources are used throughout this document in the development of a base for BPT and BAT limitations and NSPS and pretreatment standards. EPA studies as well as the literature provided the basis for subcategorization discussed in Section IV. Raw wastewater characteristics presented in Section V were obtained from the sampling program. Sampling was conducted because the available information on wastewater characteristics was inadequate. Selection of pollutant parameters for control (Section VI) was based on both dcp responses and sampling results. These provided information on both the pollutants which the plant personnel felt were in their wastewater discharges and those pollutants specifically found in canmaking wastewaters as the result of EPA sampling. Based on the selection of pollutants requiring control and their levels, applicable treatment technologies were identified and described in Section VII of this document. Actual wastewater treatment technologies utilized by canmaking plants (as identified in the dcp responses and observed at the sampled plants) were also used to identify applicable treatment technologies. The costs of treatment (both individual technologies and systems) were based primarily on data from equipment manufacturers and are contained in Section VIII of this document. Finally, dcp data, sampling data and estimated treatment system performance are utilized in Sections IX, X, XI and XII (BPT, BAT, NSPS, and pretreatment, respectively) in the selection of applicable treatment systems; the presentation of achievable effluent levels; and the presentation of actual effluent levels obtained for the canmaking subcategory.

DESCRIPTION OF THE CANMAKING SUBCATEGORY OF THE COIL COATING CATEGORY

Background

The subcategory covered by this document includes facilities which manufacture cans. Manufacturing operations may include forming, cleaning, chemically treating, and applying an organic coating to metal cans. The processing operations for making certain types of cans such as draw and iron (D&I) are somewhat similar to coil coating operations.

Historical

In 1819, William Underwood utilized a tin-plated container, patented by Peter Durand in 1810, and a process for preserving food by boiling, developed by Nichols Appart in 1809, to manufacture the first commercial tin can in the United States. However, Gail Borden's introduction of canned condensed milk in

1853 was responsible for the widespread acceptance of the can as a food container.

Cans were initially handmade until 1890 when the Norton Brothers introduced the first completely automated canmaking machine. Many other inventions and innovations have since made can manufacturing a sophisticated process. By 1960, over 200 billion food cans, 10 billion beer and beverage cans and 4 billion other nonfood cans were sold annually. The development of the pop-top tab for beer and beverage cans in 1962 marked the entry of aluminum alloys as major materials into the canmaking industry. The manufacture of a two-piece (can body and top), drawn and ironed aluminum alloy can was perfected in 1963. This container offers many advantages such as lighter weight, recycling potential, corrosion resistance and no seam leakage. The two-piece can now accounts for about 92 percent of the beverage can market.

Product Description

Can manufacturing is included within the U.S. Department of Commerce, Bureau of the Census, Standard Industrial Classification (SIC) 3411 - Metal Cans. The canmaking process produces a wide variety of sizes and shapes of metal containers which are subsequently used for storing foods, beverages and other products (e.g., deodorant or aerosol cans). A metal can is a single-walled container constructed wholly of tinplate, terneplate, blackplate (including tin-free steel), waste plate, aluminum sheet or impact extrusions and designed for packaging products.

Description of Canmaking Processes

Canmaking operations include all of the manufacturing processes and steps involved in the manufacturing of various shaped metal containers which are subsequently used for storing foods, beverages and other products. Two major types of cans are manufactured: seamed cans and seamless cans. Can bodies, and can ends and tops are made on separate lines and frequently in different plants.

Can ends and tops are manufactured by stamping and forming sheet metal (frequently plated or coil coated stock) into appropriate contours. The can ends and tops do not require washing before shipment.

Seamed cans (primarily three-piece cans) are manufactured by forming a flat piece or sheet of metal into a container with a longitudinal or side seam which is crimped, welded, or soldered, and attaching formed ends to one or both ends of the container body. About 300 plants in the United States manufacture seamed cans.

Seamed can bodies are usually fabricated by wrapping the sheet metal body around a mandrel and locking the seam. The seam may be locked by soldering, welding, or clinching with a sealant in the joint. The body is then fitted with one or both ends (bottom and top). No process wastewater is generated from these processes.

Seamless cans consist of a can body formed from a single piece of metal and usually a top (or rarely two ends) that are formed from sheet metal and attached to the can body. Beverage cans and other long cans are produced by: drawing and ironing, commonly referred to as D&I; by drawing and redrawing; or by impact extrusion. Shallow cans, such as sardine cans, are produced by drawing or stamping methods. About 125 plants in the United States manufacture seamless cans. Can ends are always produced by a stamping operation.

Drawing and Ironing (D&I)

This process sequence is shown in Figures III-1 and III-2, (pages 24 and 25). Process steps are listed and detailed below:

1. Metal coils are uncoiled.
2. Lubricants are applied and the sheet is straightened.
3. A machine called a cupper cuts a circular blank from the metal and draws the blank into a cup. Scraps of metal are collected and baled for recycle.
4. Cups are fed into the body maker which redraws the cup to the final can diameter, irons the sides to lengthen the can by thinning the metal, and places an inverted dome in the can bottom.
5. The cans are trimmed to a uniform height.
6. The cans are cleaned and the metal surface is treated.
7. Coatings and decorations are applied to the cans.
8. The open end of the can is necked and flanged to receive the can top.

Lubrication - In the manufacture of seamless can bodies oil-water emulsions are used as lubricants, coolants, and carriers for metal fines that are generated in the canmaking process. For the

D&I process sequence, different lubricants are used in the cupping and ironing steps. The cupping lubricant needs to be compatible with the residual rolling oil on the metal sheet. The redraw and D&I (or body maker) lubricants must be superior in cooling capacity. A single lubricant oil at different emulsion concentrations is sometimes used in both the cupper and body maker. This eliminates cross contamination, improves productivity, and increases lubricant batch life by facilitating reclaim and re-use.

Canmaking lubricants are based on mineral oils or synthetic oils together with solubilizing or emulsifying agents such as fatty acids, and soaps. In the canwasher, emulsified oils - those suspended in solution that will not separate by settling - are "broken" to produce free oils. These free oils can be separated from the wastewater by simple treatment means such as settling, separation, and skimming. Oil emulsions are typically broken through the use of coalescing agents.

Canwasher - Figures III-3 through III-9 (pages 26 to 32) show various configurations of canwasher water circuits and rinse stage arrangements. While not specifically referenced, they depict the hydraulic arrangements discussed in this section. The canwasher is a multifunction chemical processing machine that lies at the heart of the production of D&I cans. Nearly all of the process wastewater generated in D&I canmaking is generated by this machine. Because of the canwashers' importance in the canmaking process and in the generation of process wastewater, it is important to have a clear understanding of their operation.

Mechanical Arrangement -- The typical canwasher consists of a sequence of six stages or spray processing stations. Cans from the bodymakers are conveyed open end down sucessively through each of the stages on a continuous, open mesh metal belt. Most usually, the stages are referred to by number in the order of the movement of the cans. This convention will be observed here for ease and clarity of the discussion.

As the can moves through each stage, the processing solution is sprayed on both the inside (open or down end) and outside (upper end) of the can. At the end of each stage there may be a nonprocess space for the can to drain. Following each stage is an air knife (sometimes called a blow-off) which is used to remove the pool of liquid that is carried on the depression in the bottom of the upturned can. After the can completes its processing it is passed through a dryer that is most usually built on the canwasher frame and could be considered as another or seventh stage of the canwasher. Figures III-3 to 5 (pages 26 to 28) illustrate rinsing stages and are somewhat similar in their mechanics to the chemical application stages.

Chemical Functions -- Each of the stages of the canwasher performs a discrete function in the processing of a can. These are discussed in only brief detail below. It is recognized that the chemical and metallurgical complexities of the process cannot be fully detailed in a document of this nature; however, the level of detail is believed to be adequate for the support of this regulation and for the use of the permit writer and the POTW authority.

Stage 1 - "PREWASH" -- The primary function of this stage is to remove the heavy layer of lubricant left on the can from the bodymaker. This is accomplished primarily by the mechanical action of water being sprayed on the outside and inside of the can. The spray water is usually maintained at a slightly elevated temperature - under 50°C (120°F). The source of water for this stage may be service water (usually in canmaking this is municipal tap water) or may be water reused from a later stage. Sometimes a small amount of the processing solution from stage 2 is added to the stage 1 sump to aid in the removal of oil and to initiate the cleaning action on the cans. In some installations a preliminary prewash stage, sometimes called a vestibule rinse, is added to remove some of the heaviest of the oil coating.

Stage 2 - "ACID WASH" -- This stage is used to remove the remainder of the oil on the can, to clean or etch the surface, and to remove from the surface of the can the small bits of aluminum that become imbedded in the can surface, especially during the ironing step. In this stage as in all of the stages the processing medium is applied by spraying from both above and below the can. Most usually the processing solution used for this step is based on hydrofluoric acid, sulfuric acid and selected detergents. Because the formulations are proprietary, the exact formulation is closely held and not publicly available. Chemical reaction conditions within this stage must be closely controlled to achieve a proper balance between the amount of etching and cleaning necessary to produce an acceptable can and the costs of over cleaning and etching. The amount of etching or cleaning is determined by the balance among chemical solution strength, solution temperature, and time (determined by canwasher belt speed and stage length). The balancing of these factors is to some degree determined by the design of the canwasher; however even with the limiting factors of canwasher design, the chemical formulation, temperature and solution concentration provide ample freedom for adequate cleaning of the cans.

While most of the can cleaning formulations in use today are based on hydrofluoric acid, other commercially available etching or cleaning formulations are in use which do not use hydrofluoric acid.

Stage 3 - "RINSE" -- The principal function of this stage is to remove from the can the acid film which was dragged out from stage 2. This is accomplished by flooding the surface of the can with water. In this rinse as in other stages, the water sprayed on the can is allowed to collect in a sump or pan under the stage. Rinse water is drawn from the sump to be sprayed on the moving cans while new water is introduced into the sump or in the last spray riser and excess water along with its loading of removed chemicals and oils is overflowed from the sump to treatment. The water for rinsing may be service water or reused water from the stage 5 rinse or a combination of these.

This stage, as is any rinse stage, is critical to the proper operation of the canwasher. Failure of the rinse to reduce the level of unwanted contaminants to an acceptable level may result in an unacceptable product because of a coating of salts on the can surface or because of coating difficulties encountered in the subsequent stage.

Stage 4 - "SURFACE TREATMENT" -- In most cases cans are prepared for decorating by forming a conversion coating in the surface of the can. Chromate coatings were the standard coating for aluminum cans for many years, however the cost of chromium and the potential for environmental problems with the discharge of chromium containing wastewater has caused a shift away from this coating. A form of zirconium phosphate coating has generally replaced the chromium coating. Other coatings are technically feasible and could replace the coating currently in vogue. The purposes of the conversion coating are: to improve the appearance of the can by giving it a bright appearance; to provide a better base for the organic coating; and to protect both the appearance of the can and the adherence of the organic coatings (decorations and lining) during pasteurization of the can and contents. Some canmakers are able to make a satisfactory can without using a conversion coating.

Phosphate coatings are formed in the metal surface, incorporating metal ions into the surface to create a coating which is integrally bonded into the basis metal. Phosphating solutions consist of metal phosphates dissolved in carefully balanced solutions of phosphoric acid. Accelerators speed up film formation and prevent the polarization effect of hydrogen on the surface of the metal. In some formulations an etchant is used to remove the aluminum oxide film, allowing direct bonding of the film to the metal.

Chromate conversion coatings for aluminum may be applied from acidic or basic solutions. The acid solutions used for chromate conversion coatings usually contain one chromium salt, such as sodium chromate, or chromic acid and a strong oxidizing agent such as hydrofluoric acid or nitric acid. The exact mechanisms that cause formation of the film are not completely understood. The final film usually contains both products and reactants, and waters of hydration. Chromate films are formed by the chemical reaction of hexavalent chromium with the metal surface in the presence of "accelerators". The hexavalent chromium is partially reduced to trivalent chromium during the reaction, with a concurrent rise in pH. These reactions form a complex mixture consisting of hydrated basic chromium and chromate complexes, hydrous oxides of both chromium and the basis material ions, varying quantities of reactants, reaction products and water of hydration, as well as the associated ions of the particular system. The presence of hexavalent chromium is essential, but its concentration in chromating solutions can vary widely with limited effects as compared to the effects of fluctuation in pH.

Stage 5 - "RINSE" -- The purpose of this rinse is to remove the residual dragout from the previous stage. The factors discussed under the stage 3 rinse generally apply to this rinse.

Stage 6 - "DI RINSE -- The purpose of this stage is to rinse off the last remnants of the processing solutions from the surface of the cans. Deionized (DI) water is used to remove the maximum amount of the soluble salts from the can. The level of salts which can be tolerated on the can surface is small but not quantified. The DI rinse is usually operated as a closed system with the rinse water overflow returned to the deionizer for regeneration rather than discharged to other water uses. The used DI water is of higher quality than the service water that would have to be deionized. The wastewater discharge from this stage is the regenerate solutions from the deionizer which are sometimes located in a plant area remote to the canwasher.

Hydraulic considerations: The canwasher stages discussed in the paragraphs above are reasonably typical of the general functioning of the industry. When service water is used as the principal water feed for all of the rinse sections, the amount of water used and discharged to treatment is very large. Many procedures to reduce this wastewater have been observed in various canwashers. The most notable difference among canwashers is simply the amount of fresh (not recycled or reused) water introduced into the canwasher. Each stage uses internal recirculation to apply water to the cans, and the amount of new water introduced into the stage determines the rate of overflow from that stage, not the application rate to the cans. The final determinant of the effectiveness of any rinse stage is the achievement of equilibrium in the rinse stage between sump water and the water film remaining on the can. Figures III-6 to 9 (pages 29 to 32) illustrate the sequence of chemical processing steps, water flow patterns, water use, and water use reductions achievable using flow control and reduction technologies.

A second mechanism for reducing the waste of water in a canwasher is the internal reuse of water in the canwasher. This is usually accomplished by using the water discharged from stage 5 as the water introduced into stage 3. Additional internal reuse of water can be achieved by using the discharge from stage 3 as the water introduced into stage 1. This internal reuse of water is adequately demonstrated in many plants in the subcategory. The internal reuse of water from stage 5 to stage 3 is called counterflow rinsing. There is no valid technical reason that this internal reuse should not be done, because the materials to be removed from the can surface at each of the rinse stages are different and the presence of one material in one rinse stage will not prevent the water from effectively removing the other materials in other rinse stages. As discussed in Sections IX and X, this internal reuse of water can reduce the use of water by more than 60 percent from the median plant flow as shown by the data submitted by the canmakers in the dcp responses.

Countercurrent cascade rinsing is a technology that has received widespread use in many industries to reduce the amount of water required, or to increase the rinsing efficiency and improve product cleanliness in many metal surfacing operations. The basis of this technology is to contact the nearly clean work piece with the cleanest rinse water and use the most contaminated rinse water to remove the most concentrated drag out. This technology is detailed in Section VII of this document. It is used in this subcategory and is demonstrated as a rinsing technology for achieving lower water use levels. The potential exists for the application of countercurrent cascade rinsing to achieve substantially lower water use levels. Applying only two-stage countercurrent rinsing to stages 3 and 5 with counterflow from stage 5 to 3 presents the potential to achieve a 90 percent reduction of the water use even after applying counterflow rinsing. Similarly, the application of countercurrent cascade rinsing in stage 6, or the DI rinse, at the same DI water flow provides the opportunity for cleaner cans and assurance against product quality impacts from minor variations in the preceding processing steps.

Reuse of treated wastewater in the canwasher is another demonstrated technology for reducing the amount of wastewater which must be discharged from canwashing. One plant uses this technology in conjunction with "high technology" end-of-pipe treatment to supply a high percentage of the rinse water used in the canwasher. A second plant achieves about 50 percent utilization of treated wastewater in the canwasher.

Taken collectively all of these water flow reduction technologies can reduce water use and discharge from canwashing. Control of the hydraulic factors in canwashing is a key in achieving low pollutant discharges from canmaking.

Final Can Preparation - After cleaning, chemical treatment and drying, the cans are automatically placed onto a moving belt which takes them to the decorating line. The first step in the decoration process is often an application of a base coat followed by drying in an oven. Following this, the cans are imprinted with up to four colors. The design is applied by simultaneously spinning the print roller and the can. Immediately following that, a coat of lacquer may be applied to the bottom of the can, which then goes to a drying oven. Next the inside surface of the can is coated by spraying a food grade lacquer on the inside surface of the can and again the can is conveyed to an oven for drying.

The cans are prepared to receive a top by necking and flanging the open end of the can. The finished cans are then tested for leaks, placed onto pallets and shipped. The stages in the D&I canmaking process are shown in Figure III-1, page 24.

Draw and Redraw

This process is sometimes mistakenly called stamping. A metal blank is held between a pair of draw rings and is forced to flow over a punch to form a cup as shown in Figure III-2 (page 25). If a deeper part is required, it may be successively redrawn over progressively smaller diameter punches. Parts produced by this method can have greater depths than those produced by stamping because the movement of the metal can be controlled.

The draw and redraw process may use either coated or plain stock. When coated stock is used the lubricant employed is usually a light wax which is allowed to remain in the can and the can is shipped without washing. Plain stock is lubricated before drawing and the lubricants are removed from the can either by washing or by solvent cleaning. Lubrication and canwashing are discussed above under Drawing and Ironing.

INDUSTRY SUMMARY AND OUTLOOK

There are approximately 300 seamed can plants and 125 seamless can plants located throughout the United States and its territories. Of the 86 seamless can plants that generate wastewater, 80 are indirect dischargers, three are direct dischargers and three plants use land disposal for their wastewaters. Seamless cans account for approximately 99 percent of the beverage can market and 69 percent of total can shipments. Seamed cans make up a larger proportion of other can markets. Aluminum D&I cans account for about 73 percent of the seamless can group. Metal can shipments in 1982 totaled 89.3 billion cans.

With the U.S. economy experiencing a general slowdown, losses occurred in all except four product categories--beer, soft drink, baby foods and seafoods. Beverage cans have been growing at an annual average growth rate of 3.8 percent between 1976 and 1982, with a total of 57.9 billion units--about 65 percent of total can shipments in 1982. Beer can shipments have grown at an average annual rate of 2.8 percent. Soft drink can shipments have grown at 5.3 percent annually since 1976.

Total wastewater discharge from the canmaking subcategory is about 14.6 billion l/yr (3.8 6 billion gal/yr) with a discharge of an estimated 71,000 kg (156,528 lb) of toxic pollutants in its wastewaters every year.

TREATMENT IN PLACE

The canmaking industry has various end-of-pipe and in-process treatments already in place. Approximately ten percent of the plants have no treatment in place. The most common wastewater treatments in place as determined from dcp responses are listed below:

Treatment In Place	Percent of Plants
Chemical precipitation and settling	27
pH adjust	30
Filtration	4
Oil removal by skimming, chemical emulsion breaking, or dissolved air flotation	44

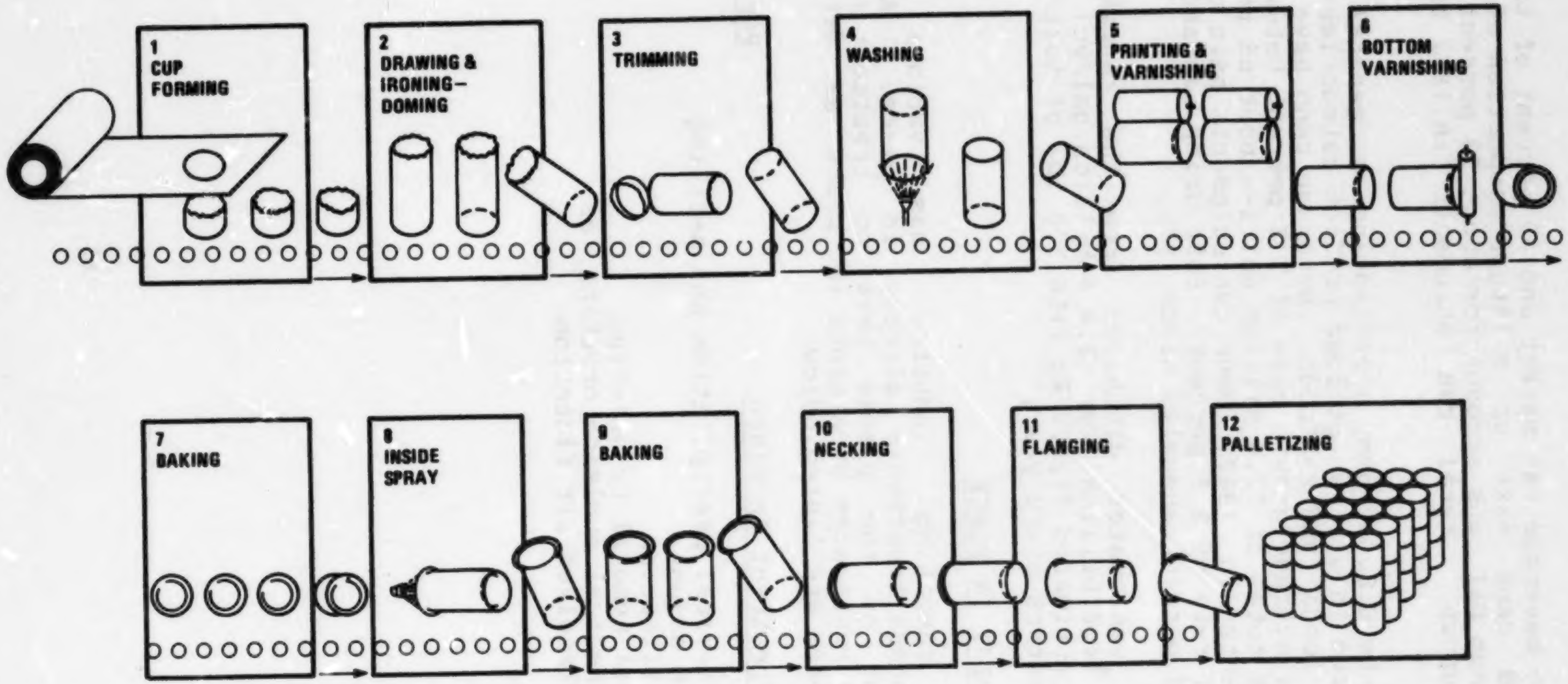
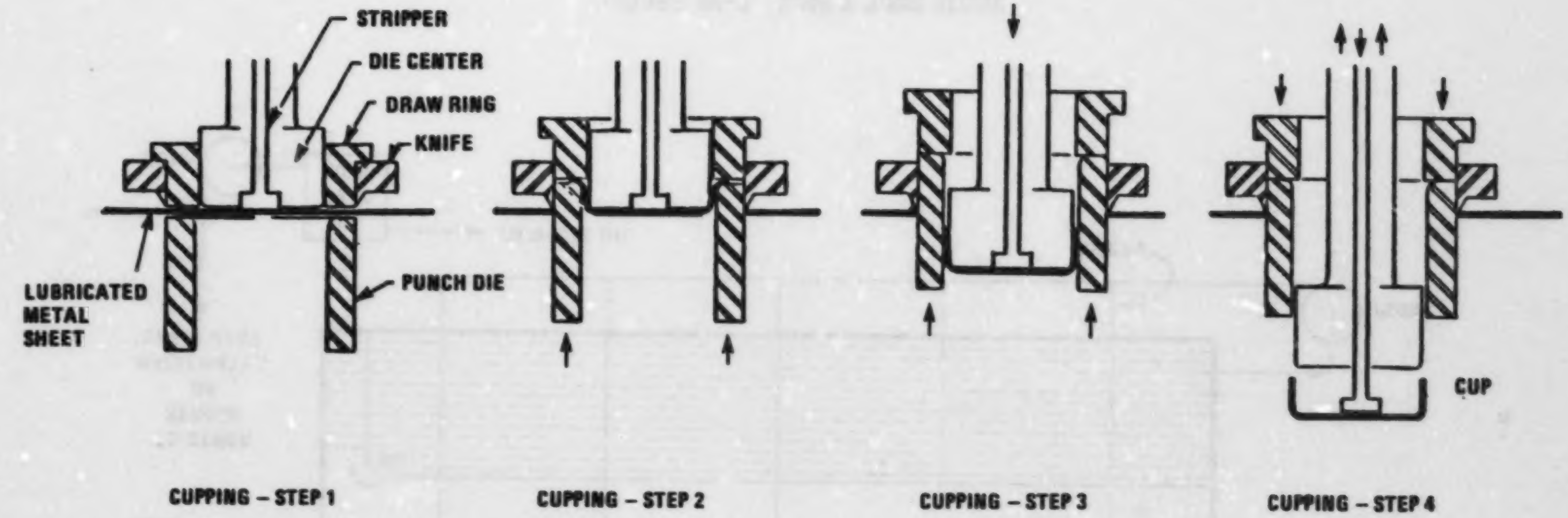
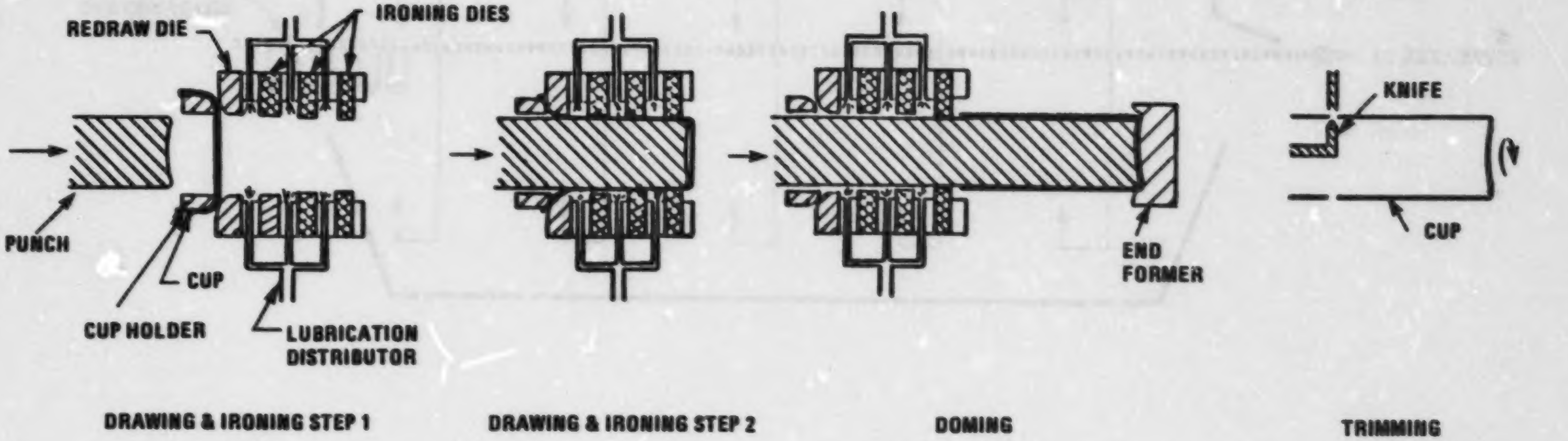

1
CUP
FORMING
2
DRAWING &
IRONING—
DOMING
3
TRIMMING
4
WASHING
5
PRINTING &
VARNISHING
6
BOTTOM
VARNISHING
7
BAKING
8
INSIDE
SPRAY
9
BAKING
10
NECKING
11
FLANGING
12
PALLETIZING

FIGURE III-1. PRODUCTION OF DRAW AND IRON CAN BODIES

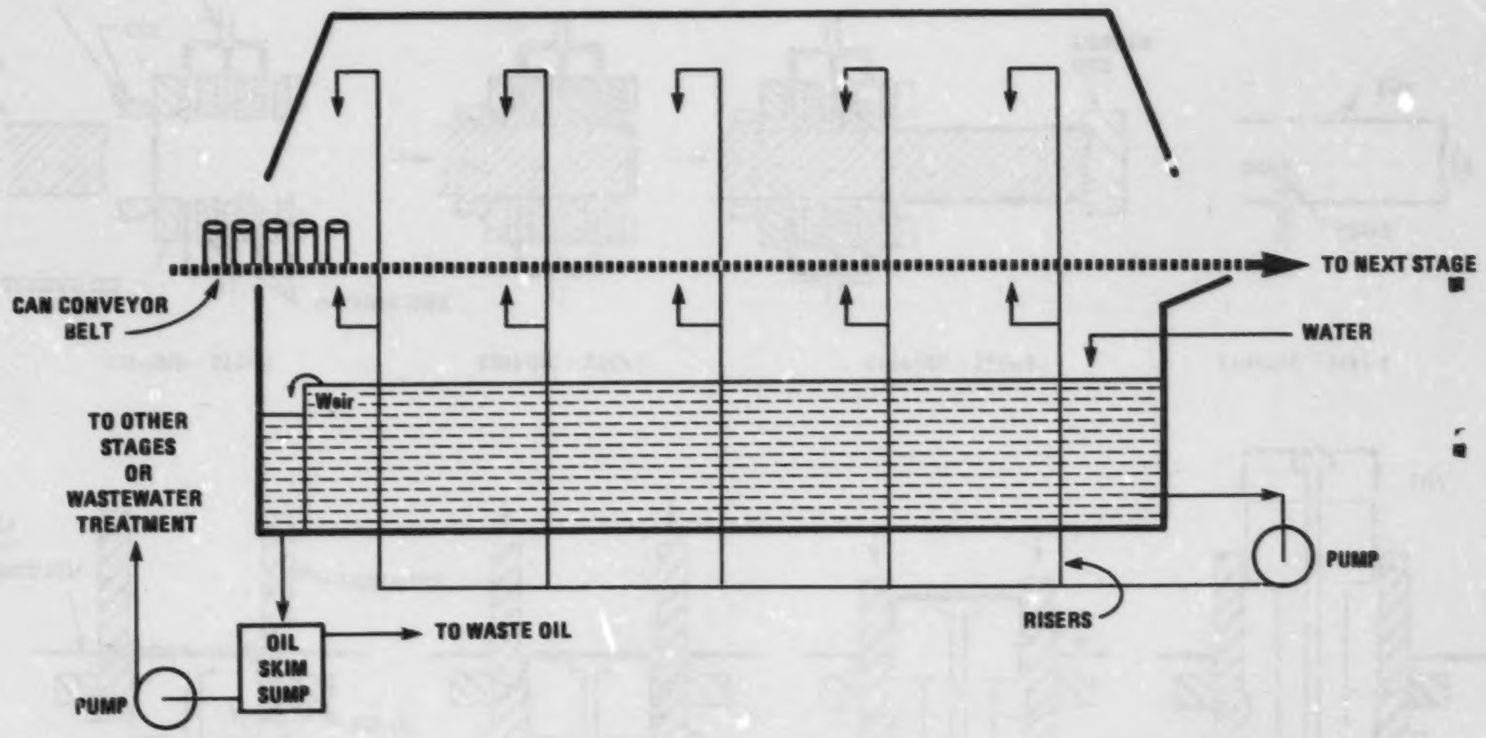

STRIPPER
DIE CENTER
DRAW RING
KNIFE
LUBRICATED METAL SHEET
PUNCH DIE
CUP

CUPPING – STEP 1 CUPPING – STEP 2 CUPPING – STEP 3 CUPPING – STEP 4


REDRAW DIE
IRONING DIES
PUNCH
CUP
CUP HOLDER
LUBRICATION DISTRIBUTOR
END FORMER
KNIFE
CUP

DRAWING & IRONING STEP 1 DRAWING & IRONING STEP 2 DOMING TRIMMING

FIGURE III-2 DETAIL OF CAN DRAWING & IRONING



TO NEXT STAGE
CAN CONVEYOR BELT
WATER
Weir
TO OTHER STAGES OR WASTEWATER TREATMENT
PUMP
OIL SKIM SUMP
TO WASTE OIL
RISERS
PUMP

FIGURE III-3. SIMPLE RINSE STAGE

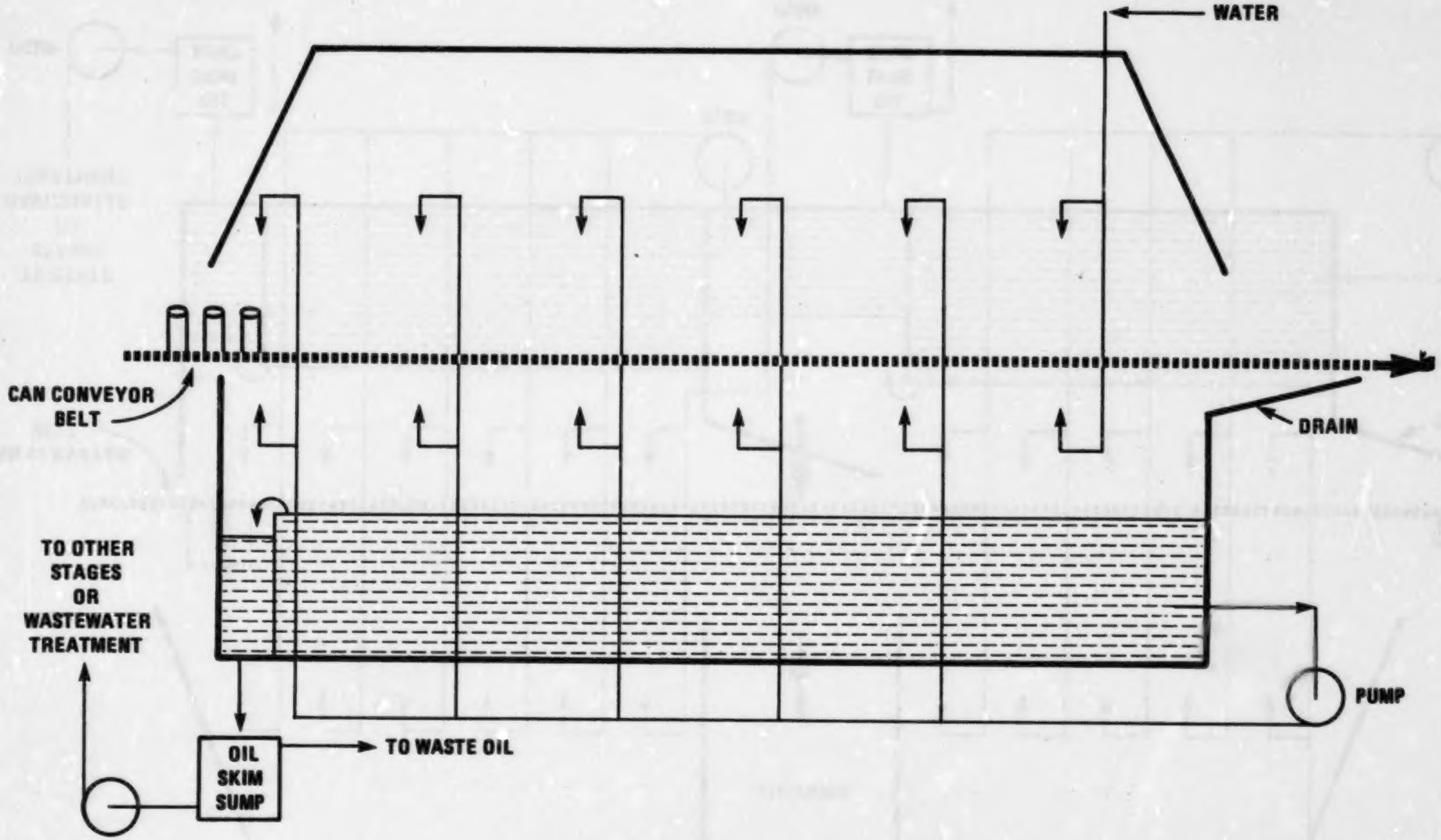

WATER
DRAIN
CAN CONVEYOR BELT
TO OTHER STAGES OR WASTEWATER TREATMENT
PUMP
OIL SKIM SUMP
TO WASTE OIL

FIGURE III - 4. SIMPLE RINSE STAGE WITH INLET WATER TO LAST RISER

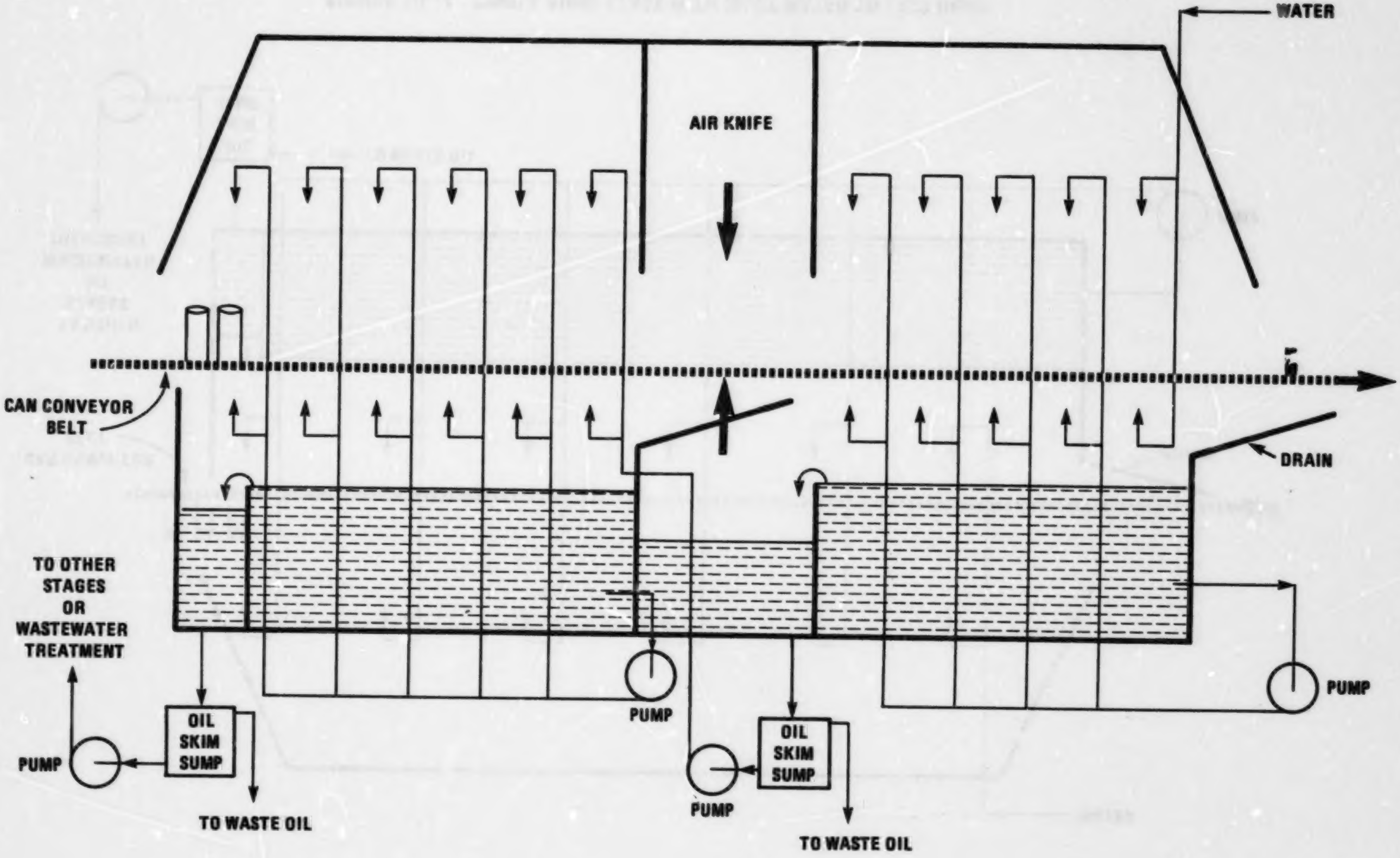

WATER
AIR KNIFE
CAN CONVEYOR BELT
DRAIN
PUMP
PUMP
PUMP
PUMP
OIL SKIM SUMP
OIL SKIM SUMP
TO WASTE OIL
TO WASTE OIL
TO OTHER STAGES OR WASTEWATER TREATMENT

FIGURE III-5. COUNTER CURRENT CASCADE RINSE STAGE

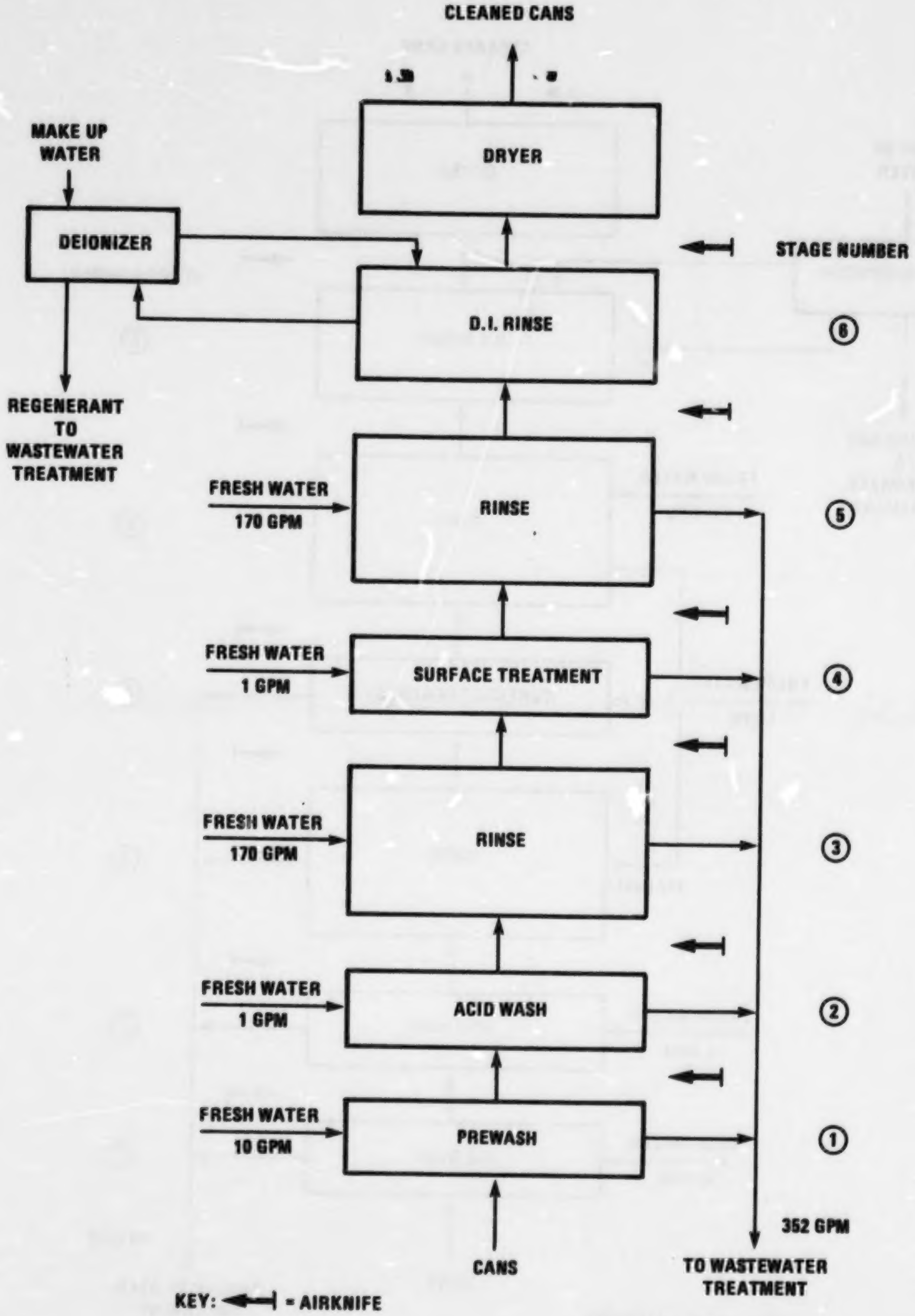

CLEANED CANS
MAKE UP WATER
DEIONIZER
DRYER
STAGE NUMBER
D.I. RINSE
⑥
REGENERANT TO WASTEWATER TREATMENT
FRESH WATER 170 GPM
RINSE
⑤
FRESH WATER 1 GPM
SURFACE TREATMENT
④
FRESH WATER 170 GPM
RINSE
③
FRESH WATER 1 GPM
ACID WASH
②
FRESH WATER 10 GPM
PREWASH
①
352 GPM
CANS
TO WASTEWATER TREATMENT
KEY: ◄—┤ = AIRKNIFE

FIGURE III-6. SIX STAGE CANWASHER – SIMPLE WATER USE

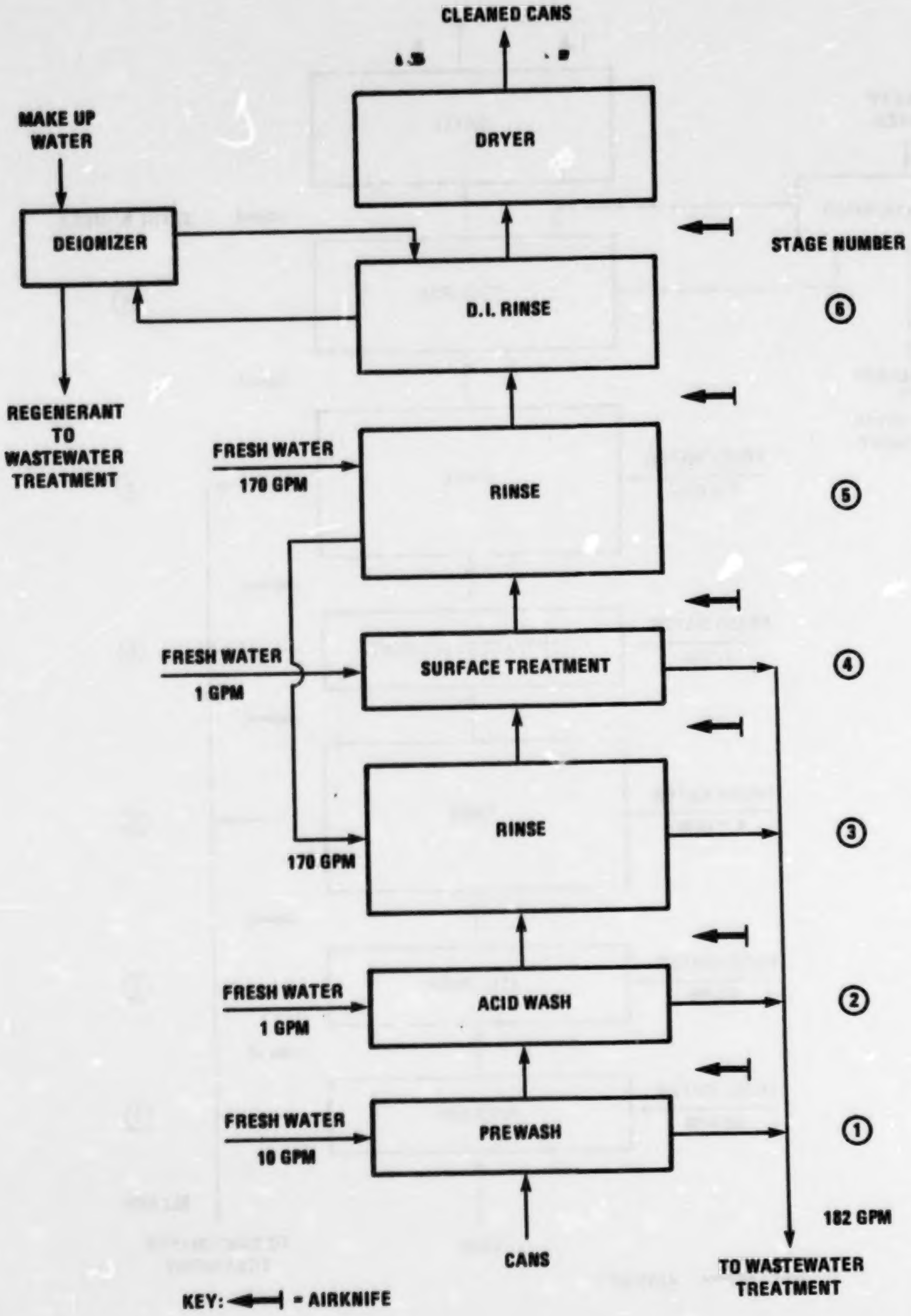

CLEANED CANS
MAKE UP WATER
DEIONIZER
DRYER
STAGE NUMBER
D.I. RINSE
⑥
REGENERANT TO WASTEWATER TREATMENT
FRESH WATER
170 GPM
RINSE
⑤
FRESH WATER
1 GPM
SURFACE TREATMENT
④
RINSE
170 GPM
③
FRESH WATER
1 GPM
ACID WASH
②
FRESH WATER
10 GPM
PREWASH
①
182 GPM
CANS
TO WASTEWATER TREATMENT
KEY: ◀—| = AIRKNIFE

FIGURE III-7. SIX STAGE CANWASHER – SIMPLE COUNTERFLOW RINSE

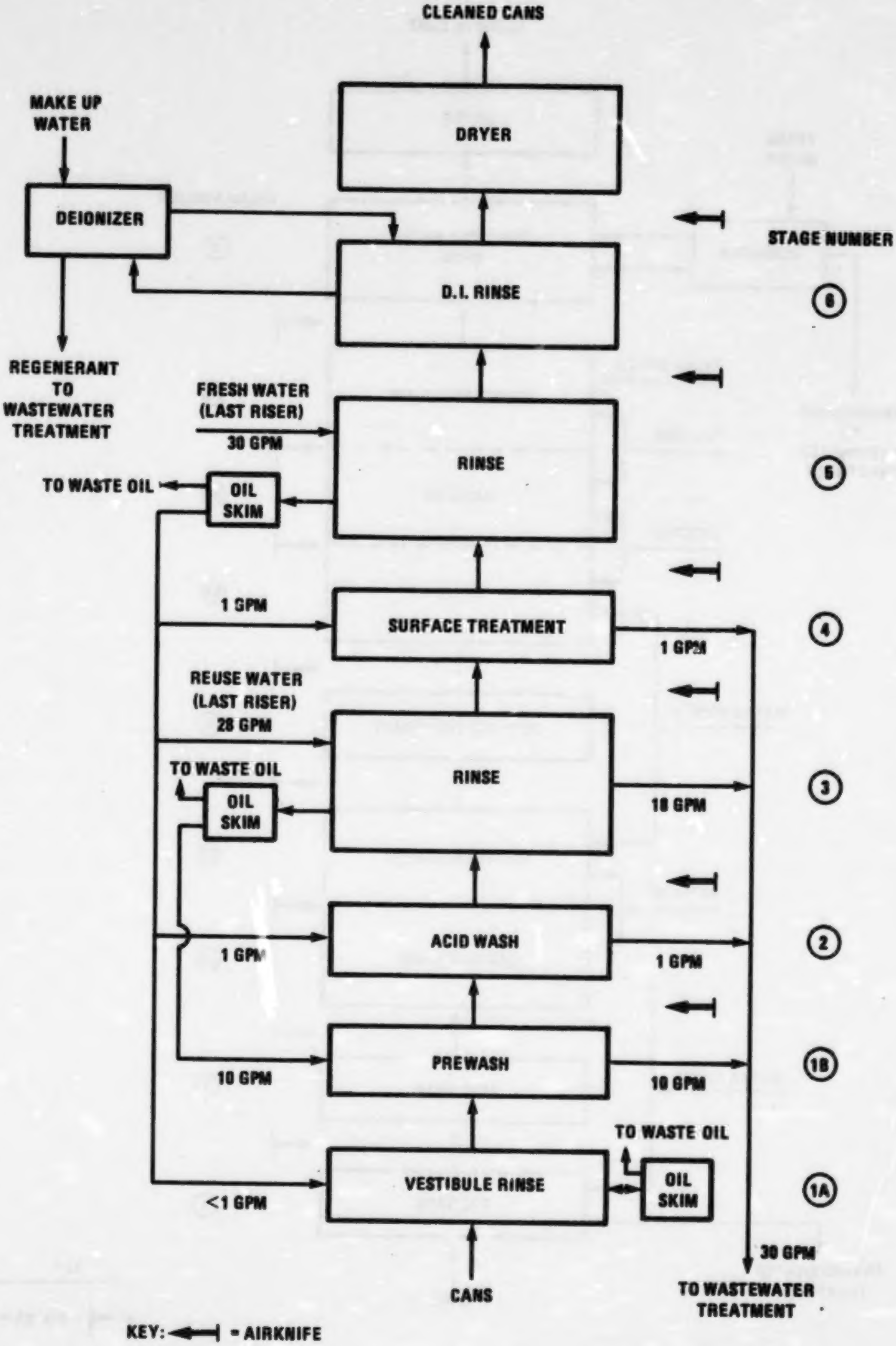

CLEANED CANS
MAKE UP WATER
DEIONIZER
DRYER
D.I. RINSE
STAGE NUMBER
6
REGENERANT TO WASTEWATER TREATMENT
FRESH WATER (LAST RISER)
30 GPM
RINSE
5
TO WASTE OIL
OIL SKIM
1 GPM
SURFACE TREATMENT
1 GPM
4
REUSE WATER (LAST RISER)
28 GPM
TO WASTE OIL
OIL SKIM
RINSE
18 GPM
3
ACID WASH
1 GPM
1 GPM
2
PREWASH
10 GPM
10 GPM
1B
TO WASTE OIL
VESTIBULE RINSE
OIL SKIM
<1 GPM
1A
30 GPM
CANS
TO WASTEWATER TREATMENT
KEY: ◄─┤ = AIRKNIFE

FIGURE III-8. SIX STAGE CANWASHER – COMPLETE COUNTERFLOW RINSE WITH LAST RISER INTRODUCTION

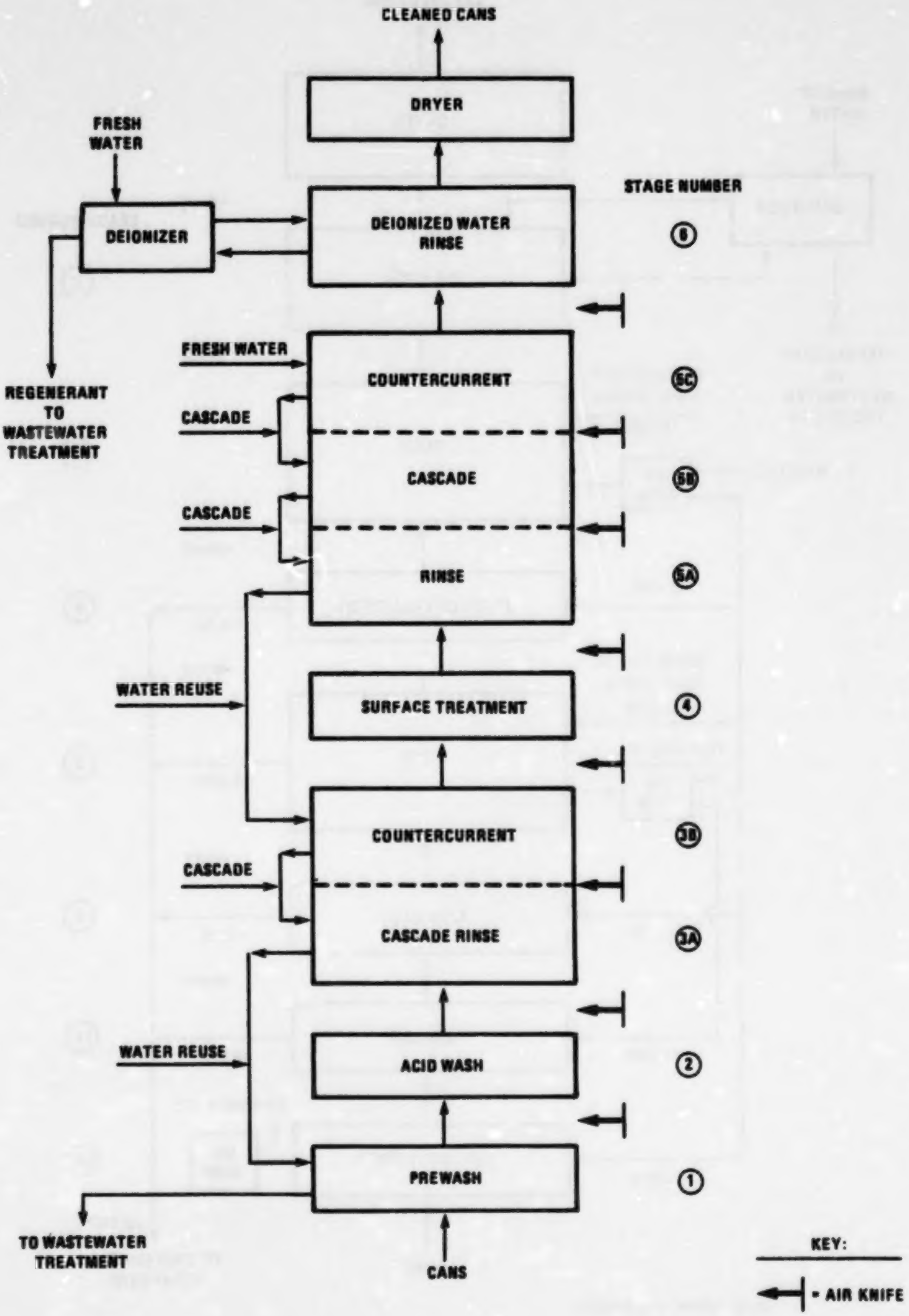

CLEANED CANS
DRYER
FRESH WATER
DEIONIZER
DEIONIZED WATER RINSE
STAGE NUMBER
6
REGENERANT TO WASTEWATER TREATMENT
FRESH WATER
COUNTERCURRENT
5C
CASCADE
CASCADE
5B
CASCADE
RINSE
5A
WATER REUSE
SURFACE TREATMENT
4
COUNTERCURRENT
3B
CASCADE
CASCADE RINSE
3A
WATER REUSE
ACID WASH
2
PREWASH
1
TO WASTEWATER TREATMENT
CANS
KEY:
= AIR KNIFE

FIGURE III-9. EXTENDED MULTISTAGE CANWASHER

SECTION IV

INDUSTRY SUBCATEGORIZATION

Subcategorization should take into account pertinent industry characteristics, manufacturing process variations, water use, wastewater characteristics, and other factors which are important in determining a specific grouping of industry segments for the purpose of regulating wastewater pollutants. Division of the category into subcategories provides a mechanism for addressing process and product variations which result in distinct wastewater characteristics. Effluent limitations and standards establish mass limitations on the discharge of pollutants and are applied, through the permit issuance process, to specific dischargers. To allow the national standard to be applied to a wide range of sizes of production units, the mass of pollutant discharge must be referenced to a unit of production. This factor is referred to as a production normalizing parameter and is developed in conjunction with subcategorization.

Division of the subcategory into segments provides a mechanism for addressing process and product variations which result in distinct wastewater characteristics. The selection of production normalizing parameters provides the means for compensating for differences in production rates among plants with similar products and processes within a uniform set of mass-based effluent limitations and standards.

SUBCATEGORIZATION BASIS

Factors Considered

For the purposes of subcategorizing canmaking EPA evaluated the following:

1. Manufacturing Processes
2. Water Use
3. Basis Material Used
4. Products Manufactured
5. Wastewater Characteristics
6. Water Pollution Control Technology and Treatment Costs
7. Solid Waste Generation and Disposal
8. Size of Plant
9. Age of Plant
10. Number of Employees
11. Total Energy Requirements
12. Nonwater Quality Environmental Aspects
13. Unique Plant Characteristics

A review of each of the possible subcategorization factors reveals that the processes performed and their use of water are the principal factors affecting wastewater characteristics of canmaking plants. Processes performed in canmaking include cupping, redrawing, drawing and ironing, trimming, washing, annealing, base coating, printing, interior coating, necking, flanging, can top stamping, welding, soldering, sealing and drying. Of these processes, those generating significant amounts of wastewater are washing, which includes rinses after cleaning and chemical treatment steps, and drawing and ironing, which use oil emulsified in water for lubricating and cooling the can material while it is being shaped. Some wastewater also may be generated by fume scrubbers used on drying ovens. The major source of pollutants in the wastewaters are the process chemicals including the lubricant and coolant oils. Other sources are the basis materials, corrosion of equipment and the organic materials trapped by fume scrubbing. The other processes that do not generate wastewater were evaluated and are not considered for regulation. They are discussed in Section III of this document.

Canwashing generates virtually all of the wastewater discharged from canmaking. Canwashing removes oils and metal particles from the surface of cans and also removes cleaning and surface treatment chemical residues from the can surface.

Subcategory Selection. Subcategorization for the canmaking industry primarily based on water use and the manufacturing process employed is the most logical method for dividing canmaking. Either processes are used for which no washing of the cans are necessary, or the specific processes used necessitate washing of the cans. All cans which are washed were considered as a single canmaking subcategory. The manufacture of seamed cans, can ends and can tops, and some seamless (draw-redraw) cans is accomplished without washing the can at the point of manufacture and thus, without generating wastewater. These canmaking processes (or segments) are not analyzed further for this regulation.

All seamless cans made from aluminum or steel by the D&I process and some seamless cans made by the draw-redraw process are washed and generate a wastewater discharge. Cans which are washed were analyzed further to determine whether additional subcategorization would be necessary. Specific factors considered for further subcategorization of cans which are washed are presented in the following subsections along with reasons why they are not appropriate for establishing additional subcategories.

Manufacturing Processes. The manufacturing processes used to make two-piece beverage cans are similar throughout the subcategory. Kaiser draw and iron technology is universally used, followed by canwashing and decorating. Other technologies have been used and are capable of being used but these are not significant factors in beverage can manufacturing today. Specifically, the Agency considered the effect of the type of lubricant used and could find no effect on the process from this aspect; also, lubricants can be substituted so that no particular lubricant must be used. A second specific factor considered was the possible effect of the surface finish of dies and tooling; no relationship to pollution control could be found. Additionally, the ability to moderate canwasher water use according to product throughput was considered; the ability to adjust water use according to production variations exists or can be added easily to a canwasher. Therefore manufacturing process does not form a basis for further subcategorization.

Water Use. Water use, particularly in the canwasher, was considered to determine if it would require additional segmentation of the subcategory. While water use rates varied among the plants in the subcategory, the Agency could find no basis in water use per se to require further segmentation of the subcategory. Similiarly, the Agency considered whether the quality of the makeup water (either the presence of contaminants or the absence of needed constituents) could require separate segmentation. The Agency concluded that incoming water could be treated to remove any unwanted contaminants or to add any needed constituents.

Basis Material Used. The basis materials washed were compared to determine whether the different basis materials should be separately subcategorized. Dcp and sampling data indicate that wastewater flows from steel cans may vary but are similar to the flows for aluminum cans (see Tables V-2 and V-3, pages 54 and 55 respectively). This range of variance is not an adequate basis for separate subcategorization. Similarily as shown in Table V-8 (page 60) less toxic metals were found in the wastewater from steel cans. However, the level of oil and grease and presumably TTO for steel cans is similar to aluminum cans, and treatable levels of toxic metals and nonconventional pollutants are generated by washing steel cans. Because these differences in wastewater characteristics and flow are small, further subcategorization based on the basis metal of cans that are washed is not appropriate.

Products Manufactured. The products produced by canmaking are metal containers used for storing foods, beverages, and other products. The cans are essentially the same and thus do not provide an apparent basis for separate segments. The Agency however evaluated a number of specific points to determine whether they formed a basis for further segmentation.

Can geometry was considered, particularly can bottom shapes, as was can height to diameter ratio. These factors do not appear to have any effect on segmentation of the subcategory. Only minor adjustments of the canwasher appear to be necessary to wash cans with different bottom shapes and height to diameter ratios.

The Agency considered the end use of the can (type of beverage stored in the can) as a factor affecting subcategorization. In particular, the claim that light or delicately flavored beers require cleaner cans than other beverages was considered. The Agency investigated the end use of cans manufactured in a wide range of plants and could find no difference in washing procedures or cleanliness requirements when cans are used for various types of beer or for other beverages. Taste and odor problems which sometimes occur in canned beer, while apparently not fully understood, appear to be related to organic compounds in lubricants used in the manufacturing process. Efficient rinsing appears to be one remedy for the problem; employing chromium surface treatment may also be an effective solution to the problem, because the strong oxidizing characteristic of chromic acid tends to destroy the organic compounds apparently responsible for the problem.

Surface coatings applied to the can, both solvent based and water based, were considered. Based on this consideration, no further segmentation appeared to be necessary. Similarily, the amount of etching necessary to achieve adequate adherence of different labels was evaluated and was not found to require separate segmentation of the subcategory.

In summary, none of the product variations evaluated appeared to require additional segmentation of the subcategory.

Wastewater Characteristics. As discussed above, the constituents of wastestreams from those process segments that generate wastewater are relatively similar and are not an appropriate basis for further subcategorization.

Water Pollution Control Technology and Treatment Costs. Water pollution control technology and treatment costs have no effect on the raw wastewater generated in a plant. The water pollution control technology employed at a plant and its cost are the result of a requirement to achieve a particular effluent level for a given raw wastewater load. It does not affect the raw wastewater characteristics, and thus does not impact subcategorization.

Solid Waste Generation and Disposal. Physical and chemical characteristics of solid waste generated by the canmaking industry are determined by the process chemicals. Furthermore, solid waste disposal techniques may be identical for a wide variety of solid wastes and do not provide a sufficient basis for subcategorization.

Size of Plant. The nature of the processes for the canmaking subcategory is the same in all facilities regardless of size. The size of a plant is not an appropriate basis for subcategorization because the wastewater characteristics of a plant per unit of production are essentially the same for plants of all sizes when processing the same basis material. Thus, size alone is not an adequate basis for segmentation since the wastewater characteristics of plants depend on the type of products produced. Similarly, the size of a canwasher does not appear to be a factor in segmentation. While running a canwasher at less than full capacity without reducing the inflow of water can increase pollutant discharge, readjustment for changes in production will eliminate this problem.

While size is not adequate as a technical segmentation parameter, EPA recognizes that the capital investment for installing wastewater control facilities may be greater for small plants relative to the investment in their production facilities than for larger plants. Consequently, the size distribution of plants was investigated during the development of limitations, and wastewater treatment technology recommendations were reviewed to determine if special considerations are required for small plants. As discussed above, wastewater pollution control requirements do not appear to be a significant factor in the economic viability of canmaking plants.

Age of Plant. While the relative age of a plant is important in considering the economic impact of a guideline, it is not an appropriate subcategorization basis because it does not reflect the fact that old plants may house equipment for seamless cans only, or they may house equipment for making both seamed cans and seamless can bodies. Since one type of operation usually generates wastewater and the other generates essentially no wastewater, the generation of process wastewater is not related to age of the plant. The age of the canwasher does not appear to be a factor in segmentation because maintenance can keep the canwasher running efficiently and the relatively small changes in canwasher design (the commercialized process is less than 20 years old) can be incorporated into existing units.

Number of Employees. The number of employees in a plant does not provide a basis for further subcategorization because the number of employees does not necessarily reflect the production or water use at any plant. Further, the rate of production depends on the process steps employed and the specific product manufactured. The amount of wastewater generated is related to the production rates, and the number of employees does not provide a definitive relationship to wastewater generation.

Total Energy Requirements. Total energy requirements were excluded as a basis for further subcategorization primarily because energy use is not directly related to pollutant discharge.

Nonwater Quality Environmental Aspects. Nonwater quality aspects are not expected to have any substantial effect on the wastewater generated in a plant. A nonwater quality control such as an air pollution control regulation could result in the use of wet scrubbers, which could result in an additional contribution to the plant's wastewater. However, the quality of water from such a source is almost miniscule in comparison to the wastewater generation in canmaking, and is therefore not acceptable as an overall subcategorization factor.

Unique Plant Characteristics. Unique plant characteristics such as geographical location, space availability, and water availability do not provide a proper basis for further subcategorization because they do not affect the raw wastewater characteristics of the plant. Plants located in arid areas are claimed to use less water; however, the water conservation practices used at these plants are applicable to all plants regardless of location. Process water availability may be a function of the geography of a plant and the price of water determines any necessary modifications to procedures employed in each plant. However, required procedural changes to account for water availability only affect the volume of pollutants discharged, not the characteristics of the constituents. Wastewater treatment procedures can be utilized in any geographical location.

A limitation in the availability of land space for constructing a wastewater treatment facility may affect the economic impact of an effluent limitation. However, in-process controls and rinse water conservation can be adapted to minimize the land space required for the end-of-process treatment facility. Often, a compact treatment unit can easily handle end-of-process waste if good in-process techniques are used to conserve raw materials and water.

PRODUCTION NORMALIZING PARAMETER

The production normalizing parameter (PNP) is used to normalize wastewater and pollutant factors and allow limitations and standards to be applied across a variety of plant sizes and production rates. In considering the canmaking subcategory three possible PNP's were considered; area of metal processed, number of cans manufactured and mass (weight) of cans manufactured.

Canmaking operations, like most metal surfacing processes, are dependent on processed area. The amount of chemicals and other raw materials used and the amount of wastewater and wastewater pollutants is proportional to the surface area processed. For this reason surface area is the first production normalizing parameter (PNP) considered. However, surface area processed is not readily available from industrial production records, and this parameter was not selected as the PNP.

A direct measure of production -- number of cans -- was next considered. Because the number of cans of any size produced is directly related to surface area processed, and because most plants maintain records in terms of numbers of cans produced, it is considered to be the best production normalizing parameter for canmaking. The difference in can sizes as it relates to can surface area was evaluated. Twelve-ounce cans comprise a very large fraction of the total beverage can output. Some sixteen-ounce cans are produced as are eight- and ten-ounce cans. Sixteen-ounce cans have about 29 percent more surface area than twelve-ounce cans while eight-ounce cans have proportionately less area. Since the other than twelve-ounce cans are small volume items, they are manufactured in plants that mostly make twelve-ounce cans and any slight difference in can area is not significant.

The weight of product manufactured was considered. However, because different basis materials are used within the subcategory, weight may vary significantly and was rejected from further consideration.

EPA has selected the number of cans produced as the production normalizing parameter.

SECTION V

WATER USE AND WASTEWATER CHARACTERIZATION

This section presents supportive data which describe and characterize canmaking water use and wastewater. Data collection and data analysis methodologies are discussed. Raw wastewater and final effluent constituents, treatment in place, and flow rates are presented for the subcategory.

INFORMATION COLLECTION

Before Proposal

Before proposal, EPA collected information from a number of sources about the canmaking industry. Some existing information was available in the Agency, including permits for canmakers who discharge to surface waters and information collected by the Office of Air Quality Planning and Standards. EPA conducted a literature search to find pertinent published information about canmaking. Technical information was provided by industry representatives and an industry trade association, the Can Manufacturer's Institute (CMI). Information requests were sent to all known canmaking companies and also to several chemical suppliers. Five canmaking plants were sampled to determine chemical and flow characteristics of the plant flows.

The National Pollutant Discharge Elimination System (NPDES) permits for canmaking facilities which had a direct discharge stream were obtained from the Regional EPA offices. Because most canmaking plants discharge wastewaters to publicly owned treatment works (POTW), a limited amount of information was received on current industry wastewater treatment practices from direct discharge plants. The permits received did not specify where the discharge streams originate and it was not possible to determine whether cooling water or other processes not under the canmaking category were included in the discharge. It also was not possible to relate the permit limitations to production, which precluded any analysis for effluent limitations except by concentration.

EPA conducted a literature search to obtain as much pertinent published material about the canmaking industry as possible. Information was collected on the processes used, the purpose of and theory behind each process, the chemicals used, the economics of the process, the methods of conserving water, and the methods of treating wastewaters from canmaking. Some of this informaton is summarized in Section III.

Preceding page blank

Industry representatives, the United States Brewers Association (USBA), and the Can Manufacturers' Institute provided information during the development of this study.

After Proposal

After proposal, EPA continued its study of the canmaking subcategory. Detailed public comments from the trade associations, individual companies, and POTW operators added to the information available for promulgating the regulation. Additional dcp were received and incorporated into the data base, and new sampling data were received from fourteen canmaking plants under the sponsorship of CMI and the USBA. All of this new data were supplemented by EPA engineering visits to 17 canmaking plants after proposal. All 14 of the plants in the CMI and USBA sampling program were visited by EPA after proposal. Additional sampling was conducted by EPA on seven of these visits.

PLANT DATA COLLECTION

Data requests were sent in 1978 to canmaking facilities in conjunction with the technical development of the aluminum forming category. In 1982 canmakers who had responded to the 1978 request were asked to update their data and other selected canmakers were asked to supply data. The 1978 data collection effort obtained information primarily about aluminum D&I canmaking and the selected data requests in 1982 were addressed primarily to manufacturers of steel cans. Information about the chemical constituents of some of the proprietary chemical baths used in canmaking was useful as a guide to the Agency on where to look for pollutants and what pollutants to expect.

In total, information on 86 aluminum and steel canmaking plants (three plants manufacture both steel and aluminum cans) that generate process wastewater was received. Some information was never received or received so late in the regulation development process that it could not be included. The Agency obtained some usable information from each of the wastewater-generating canmaking plants known to the Agency, and 92 percent supplied usable treatment in place data.

Before proposal, the number of canmaking lines at each plant was tabulated and used to characterize the size and production rate of individual plants. As a result of a further analysis of the existing canmaking data, supplemented by industry answers to a specific question about the definition of a canmaking line, the "canmaking line" is not used as the basis for production or costing analyses. The chief reason for this decision was that design philosophy in the canmaking industry has changed in recent years to place increasing emphasis on manufacturing flexibility. Many new plants and modifications of existing plants no longer dedicate equipment to a single line. Therefore, equipment that is operated as two lines one day may be operated as a single line of increased (but not double) capacity at another time. This document thus does not use the term "can line" in a definitive or quantitative sense.

Processing of Dcp Responses - Each dcp response was logged in and examined for claims of confidentiality. Information claimed to be confidential or proprietary was segregated from other information and was processed according to the EPA requirements for handling information claimed to be confidential. The dcp responses were interpreted individually and the most frequently used data transferred to a summary sheet for quick reference and evaluation. This included such data as company name, plant address, and name of the contact listed in the dcp; plant discharge status as direct (to surface water), indirect (to a POTW), or zero discharge; production process streams present, as well as the associated flow rates; production rate; operating hours; wastewater treatment, reuse, or disposal methods; the process chemicals and the type of oil used; treatment capital costs; and availability of pollutant monitoring data provided by the plant.

The calculated information derived from the most recent dcp including corrections provided in comments and verified by EPA was used throughout the study. Principal areas where the information was used include the subcategory profile, evaluation of subcategorization, analysis of in-process treatment and control technologies, and determination of water use and discharge values for the conversion of pollutant concentration to mass loadings. Each aluminum and steel plant was assigned a three digit identification number which is used throughout the study and in this document for identification.

Selection of Plants for Sampling - Information from the dcp served as the primary basis for ,selection of plants for engineering and sampling visits in 1978 and 1979. The specific criteria used to select plants for visits included:

- Manufacturing processes that are representative of the industry as a whole.
- Operating wastewater treatment systems or water conservation methods.

Engineering visits were conducted at 7 facilities prior to proposal to supplement dcp information and to review plants for possible sampling visits.

A minimum of three days of sampling was performed for each of the four plants manufacturing bodies for two-piece aluminum cans and one day of sampling for the plant manufacturing bodies for two-piece steel cans. The sampling points at each sampled plant were developed after an engineering plant visit.

After proposal additional plants were selected for engineering visits and some additional sampling. The criteria used to select these plants included:

- Inclusion of the plant in a postproposal sampling program organized and sponsored by CMI and USBA.
- Processes claimed by plant to be unique.
- Use of treatment technology not common in canmaking industry.

A total of 17 plants were visited after proposal and samples were taken at 7 of these plants.

SAMPLING PROGRAM

Methodology - Prior to sampling visits, all available data, such as plant layouts and diagrams of the production processes and wastewater treatment facilities were gathered and reviewed. Before conducting a visit, a detailed sampling plan, showing the selected sample points, was generated. Pertinent data to be obtained were detailed. For all preproposal sampling programs flow proportioned composite samples, or the equivalent for batch operations, were taken while the plant was in operation.

The purpose of the sampling and analysis program was to determine both qualitative and quantitative data about the pollutants being introduced into the wastewaters of plants in the subcategory. Plants were selected for sampling when it was possible either to sample total raw wastewater or to make a flow proportioned composite equivalent of the total raw wastewater. The total raw wastewater represents the mixed process water from all processes, mixed prior to any treatment. Many wastewaters, however, receive some preliminary treatment before mixing (e.g., chromium wastewaters may be treated to reduce hexavalent chromium before being mixed with other wastewaters). When this was the case the stream was also sampled prior to the individual stream treatment. Samples were taken for each operation which discharged or used process water, including any rinses following a treatment process.

The concentrations of parameters in the intake water to the plant were measured to see if pollutants were actually being introduced by the production operations or were present at background levels in the water being used. The analyses of these influent water samples revealed no significant quantities of pollutants. The final effluent was measured to determine the effectiveness of the wastewater treatment system. When streams were treated and discharged separately, all of the effluents were measured.

A blank sample was taken to see if any pollutants were being introduced into the other samples by the sampling equipment. A blank is made by drawing specially prepared organic-free water through the sampling equipment and handling it just as the other samples.

The samples were collected according to EPA protocol dated April 1977. The samples were collected through teflon and tygon tubing. The tygon tubing contains some of the priority pollutants; therefore, a tubing blank was collected. The methods used to analyze the samples collected are given in Sampling and Analysis Procedures for Screening of Industrial Effluents for Priority Pollutants, U.S.EPA, March 1977, Revised April 1977.

Can manufacturing wastewater samples were analyzed for organics by gas chromatography-mass spectrophotometry (GC-MS) techniques. The samples were analyzed for metals by either inductively coupled argon plasma emission spectrophotometry (ICAP) or atomic absorption spectrophotometry (AA) methods.

Pollutant 129, 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD), was not analyzed because the hazards of transporting and storing reference samples were believed to be greater than the hazard posed by the lack of routine analysis of industrial wastewaters for this compound. Pollutants (17) bis(chloromethyl ether), (49) trichlorofluoromethane, and (50) dichlorodifluoromethane have been removed from the toxics list.

The analytical methods used did not separate the concentration of certain PAH pollutant parameter pairs - specifically pollutants (72) 1,2-benzanthracene and (76) chrysene; (78) anthracene and (81) phenanthrene; and (74) 3,4-benzofluoranthene and (75) 11,12-benzofluoranthene. The total concentration of each pair is recorded once against one member of the pair.

Due to their very similar physical and chemical properties, it is extremely difficult to separate the seven polychlorinated biphenyls (pollutants 106-112 on the list of priority pollutants) for analytical identification and quantification. For that reason, the concentrations of the polychlorinated biphenyls are reported by the analytical laboratory in two groups: one group consists of (106) PCB-1242, (107) PCB-1254 and (108) PCB-1221;

the other group consists of (109) PCB-1232, (110) PCB-1248, (111) PCB-1260 and (112) PCB-1016. For convenience, the first group will be referred to as PCB-1254 and the second as PCB-1248.

The results of the asbestos self-sampling of the effluent from one canmaking plant were negative when the standard analysis procedure was used.

A number of nonpriority pollutants or pollutant parameters were also studied for the canmaking subcategory. These additional pollutants may be divided into two general groups:

Conventional

oil and grease
total suspended solids (TSS)
pH

Nonconventional

alkalinity
aluminum
calcium
chemical oxygen demand (COD)
fluoride
iron
magnesium
manganese
phenols (total)
phosphorus
sulfate
total organic carbon
total dissolved solids (TDS)

Two methods were used for oil and grease analysis. The first method (method A) was used before proposal. Because this method is affectd by fatty materials and other polar hydrocargons frequently found in canmaking wastewaters, samples taken after proposal for both the EPA and canmaker's data base used method A and another method (usually called method E). Method E eliminates the analytical interference caused by polar hydrocarbons and provides a better measure of the amount of petroleum oil and grease present. Details of the Method E are displayed in Section XV.

Two sources of information were used to identify possible pollutants in canmaking wastewaters; pollutants believed to be present by industry, and pollutants selected by the Agency after review of the processes and materials used by the industry. In the 1978 aluminum forming dcp survey, the 129 priority pollutants were listed and in the 1982 canmaking survey, the toxic metals and cyanide were listed. Each facility was asked to indicate for each particular pollutant "Known To Be Present" (KTBP), "Believed To Be Present" (BTBP), "Believed To Be Absent" (BTBA), or "Known To Be Absent" (KTBA). KTBP and KTBA were to be indicated if analyses had been performed for the pollutant and the pollutant was either detected or not detected. BTBP and BTBA were to be indicated if on the basis of knowledge of the process and materials toxic pollutants are believed to be introduced into the wastewater. For the toxic metals the results of the dcp survey for the most recent data submitted for 74 plants are shown in Table V-1 (page 53). Three pollutants (chromium, copper, and zinc) were often identified as present (KTBP or BTBP).

After proposal, public comments were submitted. In response to a specific request for additional data made by EPA in the proposal, CMI and USBA jointly organized a self-sampling program at 14 aluminum canmaking plants they judged to have properly operated proposed model treatment systems. Samples designated as total influent to and total effluent from end-of-pipe treatment were collected on each of three consecutive days. Flow and production were recorded. Analyses were performed for metal priority pollutants and several conventional and nonconventional pollutants. The results were submitted to EPA in comments. The comments stated that all applicable EPA sampling and analysis protocols were observed.

In addition, the EPA made engineering visits to 17 canmaking plants and obtained short term (4-hour) composite or grab samples of wastewater from 7 of the 17 plants. Chemical analyses were performed for toxic pollutants and some conventional and nonconventional pollutants. All 14 plants sampled under the CMI and USBA program were included in the 17 plants visited by EPA. Process wastewater streams entering treatment were characterized at all 7 plants sampled by EPA. Treated wastewater was characterized at 6 of these plants. In addition, at two plants grab samples were taken of individual process streams not treated.

Standard sampling protocols used before proposal were not employed in the postproposal sampling campaign because of the need for immediate evaluation. The samples taken were short term composites or grab samples from points in the process where equalization was accomplished by the process. Organic samples were iced for shipment and standard analysis procedures were used to determine the chemical properties of interest.

DATA ANALYSIS

Dcp, sampling data, comments, and engineering visits were used to obtain major pieces of information for further analysis including the production normalized water use (1/1000 cans) of the total canmaking process, flows for each process, the raw process wastewater pollutant levels from the total process, analyses of the raw process wastewater concentrations, and the pollutant levels, both concentration and mass, of the final effluents after wastewater treatment.

Water Use

Water is used in several key canmaking operations. It is the major component of the emulsified oils which provide cooling and lubrication during D&I operations, provides the mechanism for removing undesirable compounds from the basis material, and is the medium for the chemical reactions that occur on the basis material. Water is the medium that permits the high degree of automation associated with canmaking and the high quality of the finished product. The nature of canmaking operations, the number of cans processed, and the quantity and type of chemicals used produces a large volume of wastewater that requires treatment before discharge.

Plants provided production information in the dcp and in comments and plant visits after proposal, including annual and average hourly production rates and process wastewater discharge rates for the plant. Where sufficient information was provided, it was used to derive the production normalized water use for a plant. Production normalized water use is equal to the process water flow (liters per unit time) divided by the number of cans produced in the unit of time, multiplied by 1000 to obtain liters per 1000 cans. Table V-2 (page 54) summarizes the most recent available data for aluminum basis material can plants and Table V-3 (page 57) summarizes the information for steel basis material can plants. Several plants (column entries of "NCA") did not provide sufficient information to complete the tabulation. Three plants produce aluminum and steel cans and a separate plant ID No. was assigned for each operation. Therefore, the total number of manufacturing plants in Tables V-2, and V-3 is 86.

Before proposal, seven plants were visited and five of these plants were sampled for this subcategory; after proposal, 17 plants were visited and seven of those were sampled. The ID numbers for the visited plants, and the EPA ID numbers for the CMI & USBA sampled plants are listed in Table V-4 (page 56). Daily water flow measurements for each process were calculated and are shown in Table V-5 (page 57). Daily production information was also obtained and used to calculate the production normalized water use for each sampling day at each plant. This information is also summarized in Table V-5. Production normalized water use for the 42 plant sampling days provided by CMI & USBA are recorded in Table V-6 (page 58).

Water use data from dcp, plant visits, and postproposal comments were analyzed to determine minimum, maximum, mean and median water use at all canmaking plants. Plants practicing water reuse by means of counterflow rinsing (defined as water from stage 5 rinse counterflowed to stage 3 rinse with no fresh water added to stage 3) in the canwasher were analyzed separately. Results of this analysis are shown in Table V-7 (page 59). As shown in the water use tables the variations in flow between aluminum and steel canmaking are not substantial.

Wastewater Characterization

Chemical analysis for pollutant parameters was performed on the samples collected during the sampling program. At the five plants sampled before proposal (see Table V-4), samples of wastewater were taken from the canwasher at each discharge point. Samples were also taken at other canmaking process wastewater discharge points including oil sump discharges, ion exchange regeneration discharges, and fume scrubber discharges (see Table V-5). The canmaking processes are nearly the same in every facility. Small variations in chemical constituents and plant operation are claimed to give major advantages in product quality. Specific process detail and chemical formulations are not discussed because companies claimed that the small differences might reveal confidential information.

For each plant sampled before proposal (except for the steel plant) total raw wastewater characteristics were analyzed separately, where possible, or were flow proportioned and mathematically synthesized into the equivalent of total raw waste. Raw wastewater characteristics are displayed in Table V-8 (page 60) for each sampling day at each plant.

For the steel plant only the caustic wash sample is shown because this canwash stage is the major contributing source of pollutants for steel can manufacture. This sample was used to compare pollutants detected in steel can canwashers with the aluminum can canwasher data. As shown in Table V-8, all pollutants detected for steel were also detected in the aluminum wastewaters. Thus, the aluminum wastewaters alone can be used to represent raw wastewater for the subcategory.

The constituents in the raw wastewater include basis material, oils and components from the drawing lubricants, components of the acid treatment and conversion coating solutions, the paints and solvents used in printing the cans and the components of equipment eroded by chemicals. In Table V-8 pollutants that were not detected in any raw wastewater samples are not listed.

Chemical analyses of data include some data points of pollutants found at levels considered not quantifiable. All organics except pesticides and cyanide are considered not quantifiable at indicated concentration values equal to or less than 0.010 mg/l. Pesticides are considered not quantifiable at indicated concentration values equal to or less than 0.005 mg/l. In Table V-8 these values are indicated by an "*" for equal to or less than 0.010 mg/l and "**" for pesticides.

The distinction of not quantifiable is made because the analyses used to measure the concentrations of these pollutants are not quantitatively accurate at these concentrations. The analyses are useful, however to indicate the detection of a particular pollutant. When two or more streams were proportioned to get the total raw wastewater concentrations, the total discharge concentration was considered not quantifiable only if the total concentration was calculated exclusively from not quantifiable values. For example, a value of 0.001 mg/l for an organic is considered quantifiable if it results when a stream with a concentration of 0.020 mg/l is diluted 20 fold. For metals, the analytical methods used indicate either the detection of the metal at the amount shown or not detected at the analytical limits used.

Analytical results submitted by CMI & USBA for samples represented as total raw wastewater are presented in Table V-9 (page 62). The only pollutant parameters reported were chromium, zinc, aluminum, fluoride, phosphorus, TSS, pH, and oil and grease (methods A and E). These samples were taken either following oil removal treatment, or do not include oily wastewater streams; thus, the data do not represent total raw process wastewater for canmaking.

Results of analyses of the EPA postproposal samples of raw wastewaters are presented in Table V-10 (page 64). The preproposal sampling was more complete and acceptable for quantitative purposes. Therefore, the results of postproposal sampling have not been combined into a single flow proportioned number as was done with the data presented in Table V-8. As shown in Table V-10 toxic organic pollutants are presented in canmaking wastewaters.

A statistical analyses of the raw wastewater data from Tables V-8 and V-9 is displayed in Tables V-11 and V-12 (pages 65 and 67). Data points considered to be not quantifiable (* and **) were included in the analysis as 0.000 mg/l. This was done so as not to bias the statistical analyses.

The analysis by concentration is useful in understanding the functionality of the total canmaking process as well as each process step. High concentrations of particular constituents in a wastewater stream are indicators of the types of chemical reactions or mass transfer operations taking place.

Concentrations do not indicate the amount of pollutants being introduced into the receiving waters or sewerage system. A very large stream with low pollutant concentrations may contribute far more pollution than a very small stream with higher pollutant concentrations.

Treatment In Place

Dcp and plant visit data obtained before and after proposal (Table V-13, page 68) show that current wastewater treatment systems in the subcategory range from no treatment to sophisticated physical and chemical treatment combined with water conservation practices.

Six canmaking plants reported no treatment equipment in place. Oil removal equipment for skimming, chemical emulsion breaking or dissolved air flotation is in place at 38 canmaking plants, 3 plants have chromium reduction systems, 23 canmaking plants have pH adjustment systems without settling, 23 plants indicate they have equipment for chemical precipitation and settling, 3 plants have polishing filtration equipment in place, 1 plant has ultrafiltration on the canwasher wastewater flow, and 1 plant has reverse osmosis equipment in place. At least three plants have ultrafiltration equipment in place for treatment of the concentrated oily waste stream.

At four of the five canmaking plants sampled before proposal reuse of oil from the oil sump was practiced. At two of the 14 additional plants visited after proposal reuse of oil from the oil sump was practiced. (Four of the visited plants were visited before and after proposal.) Many other plants recycle lubricant before it reaches the sump.

Effluent Analysis

The performance of the treatment system in place at all canmaking plants is difficult to assess from the dcp because only a limited amount of canmaking effluent data was obtained from dcp and because the data is sporadic and usually unexplained. The available data are summarized in Table V-14 (page 71).

At plants visited before proposal, samples of the final effluents were taken for every day of sampling. Table V-15 (page 76) shows the effluent concentrations from each plant sampled prior to proposal that treated its wastewater for each sampling day. Total l/day for each data day are also shown. Table V-16 (page 78) presents the effluent data supplied by CMI & USBA from their sampling program. Of the plants in the CMI & USBA data base, three (ID numbers 530, 565, and 605), were judged by EPA to have properly operated lime and settle treatment in place during the sampling. Table V-17 (page 80) presents results of short-term composite effluent sample analyses from the EPA postproposal plant visits. Table V-18 (page 82) presents treated effluent data provided by Reynolds Metals Co. in their public comments.

Tables V-19, V-20 and V-21 (pages 84, 85 and 86) display the mass of pollutants discharged per 1000 cans produced. This production normalized effluent data was calculated by multiplying the concentrations for each pollutant in the concentration tables by the production normalized flow (l/1000 cans). For Table V-19, the production normalized flows for each day are those from Table V-5; for Table V-20 the production normalized flows were supplied by CMI & USBA and are presented in Table V-6; and for Table V-21, production normalized flows from Table V-2 were used.

TABLE V-1
DCP PRIORITY POLLUTANT RESPONSES

Priority Pollutant	Known to be Present	Believed to be Present	Believed to be Absent	Known to be Absent
114. Antimony	0	16	37	20
115. Arsenic	8	0	44	21
117. Beryllium	0	5	48	20
118. Cadmium	9	4	45	15
119. Chromium	50	1	22	1
120. Copper	18	30	24	2
121. Cyanide	3	10	45	15
122. Lead	24	11	35	3
123. Mercury	8	1	42	22
124. Nickel	23	10	36	4
125. Selenium	7	0	34	32
126. Silver	10	2	42	19
127. Thallium	0	6	48	19
128. Zinc	31	19	23	1

TABLE V-2
WATER USE DATA FOR CANMAKING PLANTS
ALUMINUM BASIS MATERIAL

Reuse	Plant ID	Avg. Hrly. Prod. cans/hr	Flow 1/hr	Avg. Prod. Norm. Flow 1/1000 cans	Reuse	Plant ID	Avg. Hrly. Prod. cans/hr	Flow 1/hr	Avg. Prod. Norm. Flow 1/1000 cans	Reuse	Plant ID	Avg. Hrly. Prod. cans/hr	Flow 1/hr	Avg. Prod. Norm. Flow 1/1000 cans
	000	35,775	3,754	104.9										
	002	NCA	NCA	NCA		499	177,000	55,435	313.2		605	130,000	22,742	174.9
	401	70,525	22,142	314.0		502	137,484	28,388	206.4		607	149,000	52,719	353.8
	404	198,900	47,010	236.3		508	83,710	8,289	99.0		608	100,861	8,740	86.7
	410	137,000	41,525	303.1	Y	509	125,781	15,670	124.6		613	56,320	34,065	604.8
	413	126,230	25,360	200.9		511	96,000	12,036	125.4		619	83,000	39,493	475.8
	414	38,000	11,605	305.4	Y	515	78,062	6,548	83.9		622	146,000	60,204	412.4
	423	43,600	24,712	566.8		523	106,465	39,743	373.3		626	63,416	27,631	435.7
Y	432	142,330	25,170	176.8		524	132,700	30,204	227.6		633	104,175	30,117	289.1
	434	94,150	31,037	329.7		530	104,270	9,905	95.0		642	47,254	11,389	241.0
	438A	80,429	190	2.36		539	NCA	NCA	NCA		644	86,000	15,238	177.2
	438B	80,429	1,635	20.3		541	73,260	31,416	428.8	Y	648	185,910	18,168	97.7
	441	79,800	18,509	231.9		542	62,500	7,494	119.9		661	90,363	12,634	139.8
	453	45,822	44,209	964.8		547	71,010	54,814	771.9		666A	101,000	17,033	168.6
	454	144,000	22,742	157.9		548	140,000	34,996	250.0		666B	101,000	27,252	269.8
	457	92,000	19,780	215.0		550	388,174	35,278	91.0	Y	667	84,000	6,813	81.1
Y	459	75,306	5,450	72.4	Y	555	85,725	5,450	63.6		671	NCA	NCA	NCA
Y	471	61,901	6,472	104.6		557	NCA	NCA	NCA		673	NCA	NCA	NCA
	477	73,000	16,351	224.0		558	172,000	40,163	233.5		675	31,550	24,810	786.4
	481	NCA	NCA	NCA		565	170,915	43,603	255.1	Y	678	57,271	5,450	95.2
	483	68,887	27,233	395.2	Y	577	165,890	18,849	113.6	Y	688	150,000	10,220	68.1
	485	119,500	24,527	205.2	Y	578	46,440	6,813	146.7		689	NCA	NCA	NCA
	488	63,638	7,949	124.9	Y	582	72,600	5,678	78.2	Y	692	86,775	17,127	197.4
	490	63,000	15,216	241.5		588	81,850	18,395	224.7					
	492	90,000	26,480	294.2		604	77,000	34,069	442.7					

NCA - Not Currently Available

Y - Reuse defined as water from stage 5 rinse counterflowed to stage 3 rinse with no fresh water added to stage 3.

A - Actual water use data for plant using recycle of treated wastewater in canwasher.

B - Water use of plant if recycle is not practiced.

TABLE V-3
WATER USE DATA FOR CANMAKING PLANTS
STEEL BASIS MATERIAL

Plant ID	Flow 1/hr	Avg. Hrly. Prod. cans/hr	Avg. Prod. Norm. Flow 1/1000 Cans
001	10,903	48,990	222.6
417	NCA	NCA	NCA
424	7,570	112,026	67.6
440	2,067	23,598	87.6
461	11,129	68,000	163.7
468	4,800	75,030	64.0
479	NCA	NCA	NCA
489	NCA	NCA	NCA
497	7,752	53,618	144.6
525	5,829	30,000	194.3
531	4,148	47,211	87.9
574	7,507	71,551	104.9
585	2,968	46,984	63.2
587	7,040	27,000	260.7
592	2,498	27,000	92.5
603	4,542	62,100	73.2
621	7,192	51,608	139.3
631	NCA	NCA	NCA
641	2,839	36,300	78.2
655	8,630	99,000	87.2

NCA - Not Currently Available

TABLE V-4
VISITED OR SAMPLED CANMAKING PLANTS

A. Plants visited and sampled before proposal.

	Plant ID#	Days Sampled
Aluminum	488	3
	515	3
	557	3
	565	3
Steel	655	1

B. Plants visited after proposal. Plants sampled by EPA are marked with *; all samples were four-hour composite samples or grab samples taken from points in the treatment system where equalization had occurred. All plants in the CMI & USBA sampling program are in this list and are underlined.

	Plant ID#	Plant ID#	Plant ID#
Aluminum	404	550	533
	438*	557	666
	488	565	667
	511*	578*	688*
	530*	605*	
	542*	607	
Steel	621		

TABLE V-5
SAMPLED PLANT WATER USE

Plant ID (day)	Production cans/day	Drawing Wastewater 1/day	Prewash Wastewater 1/day	Cleaning Rinse Wastewater 1/day	Chemical Treatment Rinse Wastewater 1/day	DI Regen-erant Waste-water 1/day	Wet Scrubber Wastewater 1/day	Total Waste-water 1/day	Total Water Use 1/1000 cans
ALUMINUM BASIS MATERIAL									
488(1)	1,414,134	11,355	130,810		21,802		341	164,308	116.2
488(2)	1,362,546	11,355	109,008		21,802		341	142,506	104.6
488(3)	1,263,950	11,355	98,107		21,802		341	131,605	104.1
515(1)	2,246,520		185,314					192,506	87.5
515(2)	2,386,200		185,314			7,192		185,314	77.7
515(3)	2,933,280		185,314					185,314	63.2
557(1)	943,328							261,619	277.3
557(2)	928,547							261,619	281.8
557(3)	989,289							261,619	264.5
565(1)	1,791,120		70,855	81,756	84,481			237,092	132.4
565(2)	1,791,120		111,188	62,135	104,103			277,426	154.9
565(3)	1,791,120		103,013	78,486	105,193			286,692	160.1
STEEL BASIS MATERIAL									
655(1)	1,320,000							17,259	13.08

TABLE V-6
WATER USE DATA PROVIDED BY CMI & USBA

Plant ID	Flow gal/day			Flow l/day			Production 1000 cans/day			Water Use l/1000 cans		
	1	2	3	1	2	3	1	2	3	1.0	2.0	3.0
404	346,272	348,672	320,088	1,310,640	1,319,724	1,211,533	4,429	3,927	4,888	295.9	336.1	247.9
488	NO RAW DATA PROVIDED*						1,715	1,865	1,814	79.0	72.0	75.0
511	69,120	69,120	69,120	261,619	261,619	261,619	2,344	2,295	2,248	111.6**	114.0**	116.4
530	59,339	59,666	57,769	224,598	225,836	218,656	2,425	2,285	2,093	92.6**	98.8	104.4
542	53,200	53,200	53,200	201,362	201,362	201,362	935	913	982	215.4	220.5	205.1
550	199,200	240,420	256,560	753,972	909,990	971,080	NO RAW DATA PROVIDED*			92.0	92.0	92.0
557	192,980	193,080	198,780	730,429	730,808	752,382	2,060	2,344	2,077	354.6	311.8	362.2
565	176,414	167,892	189,882	667,728	635,472	718,704	3,561	3,025	3,114	187.5	210.1	230.8
578***	47,880	47,124	48,636	181,226	178,364	184,087	1,273	1,363	1,306	142.4	130.8	141.0
605	136,800	136,800	136,800	517,788	517,788	517,788	2,955	3,378	3,151	175.2	153.3	164.4
633	200,340	179,960	201,280	758,287	681,149	761,845	2,719	3,057	2,945	278.9**	222.8**	258.7**
666	114,000	121,000	101,000	431,490	457,985	382,285	3,244	4,626	3,034	133.0	99.0**	126.0
667	41,426	40,980	53,453	156,797	155,109	202,319	2,546	2,228	1,528	61.6**	69.6	132.4
688	58,000	58,000	58,000	219,530	219,530	219,530	3,352	3,172	3,022	65.5	69.2	72.6

* Where raw data set was missing or not complete, water use (l/1000 cans) is presented directly as provided by CMI.

** Numbers were calculated from raw data supplied by CMI.

*** Effluent flow nearly double influent flow - no explanation. Effluent flow is used in this table.

TABLE V-7
SUMMARY OF WATER USE (1/1000 cans)

Data Analysis	Basis Material	Minimum	Maximum	Mean	Median	# Points
Plants Visited Before Proposal						
All Operations	Aluminum	63.2	281.8	152	124.3	12
CMI & USBA Data[1]						
All Operations	Aluminum	61.6	362.2	162.2	132.5	42
Final Water Use Data Base[2]						
All Operations for plants utilizing counterflow rinsing	Aluminum	63.6	197.4	107.4	96.4	14
All Operations	Aluminum	20.3	964.8	252.3	219.5	62
	Steel	63.2	260.7	120.7	90.2	16

[1] 14 plants self-measured for 3 days each.
[2] Includes dcp data, collected before and after proposal, and any corrections made after proposal.

TABLE V-8
SAMPLING ANALYSIS RESULTS
RAW WASTEWATER (mg/l)

Parameter	ALUMINUM BASIS MATERIAL 488(1)	488(2)	488(3)	515(1)	515(2)	515(3)	557(1)	557(2)	557(3)
4. Benzene	ND	ND	ND	*	*	*	ND	ND	ND
6. Cabron tetrachloride	ND	ND	ND	*	ND	*	ND	ND	ND
7. Chlorobenzene	ND	ND	ND	ND	ND	ND	*	ND	ND
11. 1,1,1-Trichloroethane	*	0.015	0.0118	*	*	0.034	0.980	2.8	1.100
18. Bis (2-chloroethyl) ether	ND	ND	ND	ND	0.0103	*	ND	ND	ND
23. Chloroform	ND	ND	ND	*	*	*	ND	ND	ND
29. 1,1-Dichloroethylene	ND	ND	ND	ND	ND	ND	0.050	0.170	0.060
37. 1,2-Diphenyldrazine	ND	ND	ND	ND	ND	*	ND	ND	ND
38. Ethylbenzene	ND	ND	ND	*	*	*	ND	ND	ND
44. Methylene chloride	0.019	ND	ND	0.020	0.016	0.095	*	*	*
48. Dichlorobromomethane	ND	ND	ND	*	ND	ND	ND	ND	ND
51. Chlorodibromomethane	ND	ND	ND	*	*	ND	ND	ND	ND
55. Naphthalene	ND	ND	ND	ND	*	*	ND	ND	ND
62. N-nitrosodiphenylamine	ND	ND	ND	ND	*	*	ND	ND	ND
65. Phenol	ND	ND	ND	ND	ND	*	ND	ND	ND
66. Bis (2-ethylhexyl) phthalate	ND	ND	ND	4.100	2.700	0.540	0.08	0.330	ND
67. Butyl benzyl phthalate	ND	ND	ND	ND	ND	0.022	ND	ND	ND
68. Di-n-butyl phthalate	ND	ND	ND	0.775	0.680	0.400	*	ND	ND
70. Diethyl phthalate	ND	ND	ND	ND	*	ND	ND	ND	ND
71. Dimethyl phthalate	ND	ND	ND	ND	*	*	ND	ND	ND
72. 1,2-Benzanthracene	ND	ND	ND	ND	*	*	ND	ND	ND
76. Chrysene	ND	ND	ND	ND	*	*	ND	ND	ND
78. Anthracene	ND	ND	ND	*	*	*	ND	ND	ND
80. Fluorene	ND	ND	ND	ND	*	*	ND	ND	ND
81. Phenanthrene	ND	ND	ND	*	*	*	ND	ND	ND
85. Tetrachloroethylene	ND	ND	ND	*	*	*	ND	ND	ND
86. Toluene	ND	ND	ND	0.026	0.026	0.028	*	ND	*
87. Trichloroethylene	ND	ND	ND	*	*	*	ND	ND	ND
91. Chlordane	ND	ND	ND	**	NA	NA	ND	ND	ND
92. 4-4-DDT	ND	ND	ND	**	NA	NA	ND	ND	ND
93. 4,4-DDE	ND	ND	ND	**	NA	NA	ND	ND	ND
97. Endosulfan sulfate	ND	ND	ND	**	NA	NA	ND	ND	ND
98. Endrin	ND	ND	ND	**	NA	NA	ND	ND	ND
100. Heptachlor	ND	ND	ND	**	NA	NA	ND	ND	ND
101. Heptachlor epoxide	ND	ND	ND	**	NA	NA	ND	ND	ND
102. Alpha-BHC	ND	ND	ND	**	NA	NA	ND	ND	ND
103. Beta-BHC	ND	ND	ND	**	NA	NA	ND	ND	ND
104. Gamma-BHC	ND	ND	ND	**	NA	NA	ND	ND	ND
107. PCB-1254	ND	ND	ND	**	NA	NA	ND	ND	ND
110. PCB-1248	ND	ND	ND	**	NA	NA	ND	ND	ND
115. Arsenic	0.028	0.0275	1.402	ND	ND	ND	0.0037	0.0053	0.01145
117. Beryllium	ND	ND	ND	ND	ND	ND	ND	ND	ND
118. Cadmium	0.010	0.0026	0.003	ND	ND	ND	0.0026	0.0029	0.00245
119. Chromium	0.134	0.1236	0.204	0.25	0.29	0.25	0.009	0.011	0.0195
120. Copper	0.051	0.053	0.064	0.07	0.07	0.09	0.021	0.014	0.015
121. Cyanide	0.004	0.0099	ND	0.004	0.005	0.003	ND	ND	ND
122. Lead	0.021	0.022	0.028	ND	ND	ND	0.014	0.039	0.032
123. Mercury	0.001	0.001	0.001	ND	0.0009	ND	0.0009	0.0004	0.0013
124. Nickel	0.020	0.0162	0.033	0.41	0.49	0.43	ND	ND	ND
128. Zinc	3.749	4.285	4.647	0.22	0.18	0.20	0.110	0.110	0.150
Aluminum	59.639	58.100	71.997	311	370	325	14.000	15.000	20.000
Calcium	59.107	58.044	57.504	NA	NA	NA	56.000	60.000	61.500
Fluoride	NA	NA	NA	NA	NA	NA	NA	NA	NA
Iron	1.165	1.119	1.605	5.4	5.4	5.4	0.320	0.130	0.335
Magnesium	15.221	15.299	15.05	NA	NA	NA	15.300	16.300	16.700
Manganese	0.399	0.573	0.768	4.4	5.2	4.3	0.330	0.340	0.345
Phenols	NA	NA	NA	0.014	0.020	0.019	0.016	0.010	ND
Phosphorus	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sulfate	NA	NA	NA	600	820	690	NA	NA	NA
TDS	6373	8368	8519	3096	3440	2420	NA	NA	NA
Oil & Grease	4721	44054	45094	1461	727	901	229	305	329
TSS	3309	762	837	345	275	321	96	99	77
pH				1.9	1.8	1.8	6.2	6.1	6.2

* Possibly detected but ≤0.010 mg/l
** Possibly detected but ≤0.005 mg/l
ND Not detected
NA Not analyzed

TABLE V-8 (Continued)
SAMPLING ANALYSIS RESULTS
RAW WASTEWATER (mg/l)

Parameter	ALUMINUM BASIS MATERIAL 565(1A)	565(2A)	565(3A)	565(1B)	565(2B)	565(3B)	STEEL BASIS MATERIAL 655[1]
4. Benzene	NA	NA	NA	NA	NA	NA	NA
6. Carbon tetrachloride	NA	NA	NA	NA	NA	NA	NA
7. Chlorobenzene	NA	NA	NA	NA	NA	NA	NA
11. 1,1,1-Trichloroethane	NA	NA	NA	NA	NA	NA	NA
18. Bis (2-chloroethyl) ether	NA	NA	NA	NA	NA	NA	NA
23. Chloroform	NA	NA	NA	NA	NA	NA	NA
29. 1,1-Dichloroethylene	NA	NA	NA	NA	NA	NA	NA
37. 1,2-Diphenyldrazine	NA	NA	NA	NA	NA	NA	NA
38. Ethylbenzene	NA	NA	NA	NA	NA	NA	NA
44. Methylene chloride	NA	NA	NA	NA	NA	NA	NA
48. Dichlorobromomethane	NA	NA	NA	NA	NA	NA	NA
51. Chlorodibromomethane	NA	NA	NA	NA	NA	NA	NA
55. Naphthalene	NA	NA	NA	NA	NA	NA	NA
62. N-nitrosodiphenylamine	NA	NA	NA	NA	NA	NA	NA
65. Phenol	NA	NA	NA	NA	NA	NA	NA
66. Bis (2-ethylhexyl) phthalate	NA	NA	NA	NA	NA	NA	NA
67. Butyl benzyl phthalate	NA	NA	NA	NA	NA	NA	NA
68. Di-n-butyl phthalate	NA	NA	NA	NA	NA	NA	NA
70. Diethyl phthalate	NA	NA	NA	NA	NA	NA	NA
71. Dimethyl phthalate	NA	NA	NA	NA	NA	NA	NA
72. 1,2-Benzanthracene	NA	NA	NA	NA	NA	NA	NA
76. Chrysene	NA	NA	NA	NA	NA	NA	NA
78. Anthracene	NA	NA	NA	NA	NA	NA	NA
80. Fluorene	NA	NA	NA	NA	NA	NA	NA
81. Phenanthrene	NA	NA	NA	NA	NA	NA	NA
85. Tetrachloroethylene	NA	NA	NA	NA	NA	NA	NA
86. Toluene	NA	NA	NA	NA	NA	NA	NA
87. Trichloroethylene	NA	NA	NA	NA	NA	NA	NA
91. Chlordane	NA	NA	NA	NA	NA	NA	NA
92. 4,4-DDT	NA	NA	NA	NA	NA	NA	NA
93. 4,4-DDE	NA	NA	NA	NA	NA	NA	NA
97. Endosulfan sulfate	NA	NA	NA	NA	NA	NA	NA
98. Endrin	NA	NA	NA	NA	NA	NA	NA
100. Heptachlor	NA	NA	NA	NA	NA	NA	NA
101. Heptachlor epoxide	NA	NA	NA	NA	NA	NA	NA
102. Alpha-BHC	NA	NA	NA	NA	NA	NA	NA
103. Beta-BHC	NA	NA	NA	NA	NA	NA	NA
104. Gamma-BHC	NA	NA	NA	NA	NA	NA	NA
107. PCB-1254	NA	NA	NA	NA	NA	NA	NA
110. PCB-1248	NA	NA	NA	NA	NA	NA	NA
115. Arsenic	ND	ND	ND	ND	ND	ND	ND
117. Beryllium	NA	NA	NA	NA	NA	NA	ND
118. Cadmium	ND	ND	ND	ND	ND	ND	ND
119. Chromium	2.106	1.878	5.410	0.777	1.160	2.468	0.020
120. Copper	0.017	0.019	0.028	0.015	0.019	0.020	ND
121. Cyanide	0.031	0.026	0.031	0.034	0.028	0.034	NA
122. Lead	ND	ND	0.052	ND	ND	ND	0.005
123. Mercury	ND	ND	ND	ND	ND	ND	NA
124. Nickel	ND	0.008	ND	ND	0.010	ND	0.040
128. Zinc	0.037	0.033	0.037	0.041	0.036	0.029	ND
Aluminum	NA	NA	NA	NA	NA	NA	NA
Calcium	NA	NA	NA	NA	NA	NA	NA
Fluoride	15.66	15.36	16.75	16.99	17.65	18.02	0.880
Iron	0.146	0.142	0.159	0.131	0.142	0.162	0.700
Magnesium	NA	NA	NA	NA	NA	NA	NA
Manganese	NA	NA	NA	NA	NA	NA	0.012
Phenols	0.013	0.010	0.009	0.013	0.007	0.009	NA
Phosphorus	5.88	5.067	12.90	3.216	3.091	6.23	16.50
Sulfate	NA	NA	NA	NA	NA	NA	NA
TDS	NA	NA	NA	NA	NA	NA	NA
Oil & Grease	196.6	139.1	226.2	193.3	134.6	222.2	140.0
TSS	182.9	121.18	178.4	181.5	111.5	167.9	96.5
pH							8.6

[1] Sample analysis from caustic wash stage
* Possibly detected but ≤0.010 mg/l
** Possibly detected but ≤0.005 mg/l
ND Not detected
NA Not analyzed

TABLE V-9
CMI & USBA SAMPLED PLANTS RAW WASTEWATER DATA (mg/1)*

Parameter	404(1)	404(2)	404(3)	488(1)	488(2)	488(3)	511(1)	511(2)	511(3)	530(1)	530(2)	530(3)
119. Chromium	0.80	0.40	0.20	0.10	0.20	0.10	0.20	0.20	0.20	36.00	34.00	31.00
128. Zinc	0.50	0.20	0.10	1.20	1.40	0.70	0.10	0.10	0.10	0.20	0.20	0.20
Aluminum	382.00	176.00	130.00	167.00	283.00	165.00	80.00	90.00	85.80	101.00	106.00	96.80
Fluoride	152.00	69.00	117.00	145.00	210.00	170.00	95.00	100.00	66.00	82.00	53.00	61.00
Phosphorus	0.10	0.50	0.50	0.20	0.20	0.20	0.10	0.10	0.10	1.20	2.90	10.00
pH	5.30	5.30	5.50	2.23	4.45	NA	2.90	2.80	2.60	2.40	2.30	2.70
TSS	1444.00	156.00	63.00	598.00	1240.00	297.00	33.50	43.50	34.00	61.00	65.00	70.50
O&G-A	1700.00	1200.00	500.00	61.70	770.00	74.50	161.00	166.00	171.00	182.00	318.00	267.00
O&G-E	1050.00	842.00	244.00	227.00	343.70	338.00	45.20	45.40	43.50	67.80	121.00	96.40

Parameter	542(1)	542(2)	542(3)	550(1)	550(2)	550(3)	557(1)	557(2)	557(3)	565(1)	565(2)	565(3)
119. Chromium	0.10	0.10	0.10	1.10	1.10	0.70	NA	NA	NA	0.06	0.05	0.06
128. Zinc	0.10	0.10	0.10	0.60	0.90	0.40	NA	NA	NA	0.05	0.04	0.03
Aluminum	120.00	130.00	80.50	192.00	220.00	165.00	NA	NA	NA	67.40	50.20	59.30
Fluoride	21.00	13.50	22.40	198.00	198.00	130.00	NA	NA	NA	107.00	116.00	48.00
Phosphorus	2.80	1.00	0.10	1.00	0.10	0.10	NA	NA	NA	3.03	2.53	3.94
pH	5.50	5.50	5.50	NA	NA	NA	6.88	6.83	6.80	NA	NA	NA
TSS	34.00	21.00	23.50	282.00	352.00	146.00	NA	NA	NA	155.80	72.60	36.60
O&G-A	179.00	209.00	70.10	89.30	88.30	118.00	NA	NA	NA	98.50	180.40	150.80
O&G-E	78.60	95.00	24.80	35.90	40.20	49.40	NA	NA	NA	61.00	127.00	94.00

* Data recorded as submitted by CMI & USBA. The raw wastewater analyzed by CMI & USBA do not include all sources of raw wastewater from canmaking operations. Oily wastewaters were excluded or pretreated in every case, and other sources of pollutants such as scrubbers were not always included.

NA - Not Available.

TABLE V-9 (Continued)
CMI & USBA SAMPLED PLANTS RAW WASTEWATER DATA (mg/l)*

Parameter	578(1)	578(2)	578(3)	605(1)	605(2)	605(3)	633(1)	633(2)	633(3)	666(1)	666(2)	666(3)
119. Chromium	0.10	0.10	0.10	0.10	0.20	0.20	0.20	0.20	0.20	0.20	0.10	0.20
128. Zinc	0.10	0.10	0.10	0.20	0.10	0.10	0.30	0.20	0.30	0.10	0.10	0.10
Aluminum	75.90	83.60	86.90	110.00	114.00	129.00	88.00	85.80	77.00	48.00	30.00	75.90
Fluoride	82.00	100.00	74.00	81.00	90.00	130.00	39.50	26.00	26.00	95.00	43.00	100.00
Phosphorus	0.10	0.10	0.10	12.30	17.40	14.20	0.10	0.10	0.10	0.10	0.50	0.10
pH	4.96	5.02	4.60	6.20	2.70	2.50	2.50	2.50	2.50	6.20	2.80	NA
TSS	30.50	33.00	34.50	18.00	10.40	16.90	32.00	31.20	43.80	29.50	38.00	40.00
O&G-A	208.00	219.00	285.00	72.80	94.90	110.00	119.00	104.00	124.00	29.30	29.80	NA
O&G-E	103.00	43.00	136.00	20.90	16.20	16.10	56.10	49.90	78.20	9.10	4.60	NA

Parameter	667(1)	667(2)	667(3)	688(1)	688(2)	688(3)
119. Chromium	0.10	0.10	0.10	0.55	0.20	0.30
128. Zinc	0.10	0.10	0.10	0.20	0.10	0.20
Aluminum	97.90	108.00	100.00	280.00	170.00	190.00
Fluoride	61.00	100.00	100.00	250.00	138.00	170.00
Phosphorus	0.10	0.10	0.10	0.10	1.50	0.10
pH	4.60	3.00	3.30	4.90	5.50	8.00
TSS	83.00	71.00	56.00	116.00	99.50	56.50
O&G-A	130.00	278.00	161.00	526.00	266.00	181.00
O&G-E	63.10	144.00	92.00	162.00	89.00	61.90

* Data recorded as submitted by CMI & USBA. The raw wastewater analyzed by CMI & USBA do not include all sources of raw wastewater from canmaking operations. Oily wastewaters were excluded or pretreated in every case, and other sources of pollutants such as scrubbers were not always included.

NA - Not Available.

Table V-10
POSTPROPOSAL EPA SAMPLING ANALYSIS RESULTS
RAW WASTEWATER (mg/1)

Parameter	438(1)	511(1) Canwasher	511(1)(2) Tramp oil	530(1)	542(3)	542(1)	578(3)	605(1)	688(1) Canwasher	688(1) Pit Waste	688(1) Scrubber
4. Benzene	ND	ND	ND	*	*	ND	ND	NA	NA	NA	NA
15. 1,1,2,2-Tetrachloroethane	ND	ND	0.055	ND	ND	ND	ND	NA	NA	NA	NA
18. Bis(2-chloroethyl)ether	0.071	ND	ND	ND	0.158	0.157	*	NA	NA	NA	NA
23. Chloroform	*	*	ND	*	*	*	*	NA	NA	NA	NA
30. 1,2-Transdichloroethylene	ND	ND	ND	ND	*	ND	ND	NA	NA	NA	NA
44. Methylene Chloride	ND	*	ND	0.070	*	*	0.024	NA	NA	NA	NA
47. Bromoform	*	*	ND	ND	ND	ND	ND	NA	NA	NA	NA
65. Phenol	ND	ND	ND	ND	ND	*	ND	NA	NA	NA	NA
66. Bis(2-ethylhexyl)phthalate	0.036	ND	ND	*	0.026	ND	0.013	NA	NA	NA	NA
67. Butyl benzyl phthalate	ND	ND	ND	ND	0.463	0.199	ND	NA	NA	NA	NA
68. Di-n-butyl phthalate	*	ND	ND	*	ND	*	ND	NA	NA	NA	NA
71. Dimethyl phthalate	*	ND	ND	ND	ND	ND	ND	NA	NA	NA	NA
81. Phenanthrene	ND	ND	0.044	ND	ND	ND	ND	NA	NA	NA	NA
85. Tetrachloroethylene	ND	ND	ND	ND	*	*	ND	NA	NA	NA	NA
86. Toluene	*	*	1.269	ND	*	ND	*	NA	NA	NA	NA
117. Beryllium	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
118. Cadmium	ND	ND	ND	ND	ND	NA	ND	ND	ND	ND	ND
119. Chromium	1.780	0.260	ND	29.100	0.180	NA	0.080	0.040	0.340	ND	ND
120. Copper	0.650	ND	ND	ND	ND	NA	ND	ND	ND	ND	ND
122. Lead	0.050	ND	0.500	ND	ND	NA	0.050	ND	ND	ND	ND
124. Nickel	1.250	0.150	ND	0.100	0.150	NA	0.050	ND	0.250	ND	ND
128. Zinc	0.480	0.060	3.800	0.260	0.080	NA	0.100	0.080	0.120	0.460	ND
Aluminum	350.000	117.000	67.000	105.000	33.3	NA	82.200	49,500	193.000	9.800	ND
Barium	ND	ND	ND	0.050	ND	NA	0.200	ND	0.100	ND	0.100
Boron	1.100	0.100	4.000	ND	0.400	NA	ND	4,800	0.600	12.700	0.100
Calcium	2.300	12.000	14.000	60.300	31.100	NA	70.700	12.200	80.600	131.000	81.900
Cobalt	ND	ND	ND	ND	ND	NA	ND	ND	ND	ND	ND
Fluoride	NA	150.000	23.000	94.000	33.0	NA	120.000	52.000	220.000	2.300	0.330
Iron	11.500	1.450	7.500	1.200	1.850	NA	0.750	0.450	2.050	8.700	0.200
Magnesium	8.200	4.500	17.000	17.6	11.100	NA	28.400	19.300	38.200	112.000	34.900
Manganese	3.400	1.200	ND	0.900	0.350	NA	1.000	0.500	1.750	0.500	ND
Molybdenum	0.200	ND	ND	ND	ND	NA	ND	ND	ND	ND	ND
Phosphorus	NA	0.220	NA(4)	27.00	0.360	NA	0.690	5.800	0.100	10.000	0.070
Sodium	59.100	8.300	112.000	505.000	5.400	NA	5.000	40.800	77.200	392.000	83.600
Tin	ND	ND	ND	ND	ND	NA	ND	ND	ND	ND	ND
Titanium	0.050	ND	ND	ND	ND	NA	ND	ND	ND	ND	ND
Vanadium	0.050	ND	ND	ND	ND	NA	ND	ND	ND	ND	ND
Yttrium	ND	ND	ND	ND	ND	NA	ND	ND	ND	ND	ND

(1) Sampled collected in plastic container.
(2) Detection limits for metals raised due to interferences. Sample diluted.
(3) Sample collected in glass container.
(4) Nonfilterable turbidity prevented spectrophotometric analysis for phosphorus.
* Possibly detected but ≤ 0.010 mg/1.

NA Not Analyzed
ND Not Detected

TABLE V-11
STATISTICAL ANALYSIS
RAW WASTEWATER POLLUTANTS (mg/l)
ALUMINUM BASIS MATERIAL

Parameter	Minimum	Maximum	Mean	Median	# Quantifiable Points	# Not Detected Points	# Nonquantifiable Points
4. Benzene	*	*	*	*	0	6	3
6. Carbon tetrachloride	*	*	*	*	0	7	2
7. Chlorobenzene	*	*	*	*	0	8	1
11. 1,1,1-Trichloroethane	*	2.8	0.561	0.034	6	0	3
18. Bis (2-chloroethyl) ether	*	0.0103	*	*	1	6	1
23. Chloroform	*	*	*	*	0	6	3
29. 1,1-Dichloroethylene	0.050	0.170	0.093	0.060	3	6	0
37. 1,2-Diphenylhydrazine	*	*	*	*	0	8	1
38. Ethylbenzene	*	*	*	*	0	6	3
44. Methylene chloride	*	0.095	0.022	0.016	4	2	3
48. Dichlorobromomethane	*	*	*	*	0	8	1
51. Chlorodibromomethane	*	*	*	*	0	7	2
55. Naphthalene	*	*	*	*	0	7	2
62. N-nitrosodiphenylamine	*	*	*	*	0	7	2
65. Phenol	*	*	*	*	0	8	1
66. Bis (2-ethylhexyl) phthalate	0.08	4.100	1.55	0.540	5	4	0
67. Butyl benzyl phthalate	0.022	0.022	0.022	0.022	1	8	0
68. Di-n-butyl phthalate	*	0.775	0.464	0.540	3	5	1
70. Diethyl phthalate	*	*	*	*	0	8	1
71. Dimethyl phthalate	*	*	*	*	0	7	2
72. 1,2-Benzanthracene	*	*	*	*	0	7	2
76. Chrysene	*	*	*	*	0	7	2
78. Anthracene	*	*	*	*	0	6	3
80. Fluorene	*	*	*	*	0	7	2
81. Phenanthrene	*	*	*	*	0	6	3

TABLE V-11(Continued)
STATISTICAL ANALYSIS
RAW WASTEWATER POLLUTANTS (mg/l)
ALUMINUM BASIS MATERIAL

Parameter		Minimum	Maximum	Mean	Median	# Quantifiable Points	# Not Detected Points	# Nonquantifiable Points
85.	Tetrachloroethylene	*	*	*	*	0	6	3
86.	Toluene	*	0.028	0.016	0.026	3	4	2
87.	Trichloroethylene	*	*	*	*	0	6	3
91.	Chlordane	**	**	**	**	0	6	1
92.	4,4-DDT	**	**	**	**	0	6	1
93.	4,4-DDE	**	**	**	**	0	6	1
97.	Endosulfan sulfate	**	**	**	**	0	6	1
98.	Endrin	**	**	**	**	0	6	1
100.	Heptachlor	**	**	**	**	0	6	1
101.	Heptachlor epoxide	**	**	**	**	0	6	1
102.	Alpha-BHC	**	**	**	**	0	6	1
103.	Beta-BHC	**	**	**	**	0	6	1
104.	Gamma-BHC	**	**	**	**	0	6	1
107.	PCB-1254	**	**	**	**	0	6	1
110.	PCB-1248	**	**	**	**	0	6	1
115.	Arsenic	0.0037	1.402	0.246	0.019	6	9	
118.	Cadmium	0.0026	0.010	0.004	0.003	6	9	
119.	Chromium	0.009	5.41	1.006	0.25	15	0	
120.	Copper	0.014	0.09	0.038	0.021	15	0	
121.	Cyanide	0.003	0.034	0.019	0.026	11	4	
122.	Lead	0.014	0.052	0.030	0.028	7	8	
123.	Mercury	0.0004	0.0013	0.0009	0.001	7	8	
124.	Nickel	0.008	0.49	0.177	0.027	8	7	
128.	Zinc	0.029	4.647	0.924	0.110	15	0	
	Aluminum	14.000	370	138.3	59.639	9	0	
	Fluoride	15.36	18.02	16.74	16.87	6	0	
	Iron	0.13	5.4	1.397	0.32	15	0	
	Manganese	0.33	5.2	1.851	0.573	9	0	
	Phenols	0.007	0.02	0.013	0.013	11	1	
	Phosphorus	3.091	12.9	6.06	5.47	6	0	
	Oil & Grease	134.6	45094	6596	305	15	0	
	TSS	77	3309	471	181.5	15	0	

* Possibly detected but ≤0.010 mg/l.

** Possibly detected but ≤0.005 mg/l.

TABLE V-12
STATISTICAL ANALYSIS - CMI & USBA
RAW WASTEWATER DATA (mg/l)
ALUMINUM BASIS MATERIAL

Parameter	Minimum	Maximum	Mean	Median	# Points
119. Chromium	0.05	36.00	2.82	0.20	39
128. Zinc	0.03	1.40	0.25	0.10	39
Aluminum	30.00	382.00	125.60	101.00	39
Fluoride	13.50	250.00	99.50	95.00	39
Phosphorus	0.10	17.40	2.00	0.10	39
TSS	10.40	1440.00	155.50	56.00	39
O&G-A	29.30	1700.00	255.00	163.50	38
O&G-E	4.60	1050.00	137.20	73.00	38

TABLE V-13
TREATMENT IN PLACE

		CANWASHER WASTE STREAM						OILY WASTE STREAM							
ID	NOTES	EQUAL	OIL REM	PREC	SOL REM	FIN pH ADJ	SLUDGE DEWAT	SEP	HAUL NO PRE	PRETREAT	OILY FRACTION	H_2O FRACTION	DI	ACTIVATED CARBON BACKWASH	SCRUBBER AND MISC.
	ALUMINUM BASIS MATERIAL														
000	1 DAF unit total Scrubber H_2O to POTW	Yes	DAF	ALUM/NaOH/ POLY	DAF/SETL		PRES	Y		POLY/NaOH	RCLM	WWT	POTW		POTW
002	1 DAF unit total		CEB/DAF	NaOH/POLY	DAF			Y	Y				POTW		
401	lab sink & fume hood H_2O to WWT			LIME/POLY	LAM		VAC FILT	Y		ACID/SKIM	HAUL	WWT	WWT		WWT
404	2 DAF units total	Yes	DAF	NaOH/POLY	DAF/FILT			Y		GRAV	HAUL	WWT	WWT		
410	noncontact H_2O to WWT		CEB/SKIM	LIME/POLY	CLAR		PRES	N					WWT	WWT	WWT
413						Y		Y	Y				WWT		
414	1 DAF unit total		DAF	NaOH/POLY	DAF/FILT		PRES	Y		SKIM	UNS	WWT	WWT	WWT	
423	No WWT							Y	Y				POTW		
432		Yes				Y		Y		PRES	HAUL	WWT	WWT	WWT	
434						Y		Y	Y				WWT		
438		Yes	UF/RO					N					WWT	WWT	WWT
441		Yes	GRAV			Y		Y	Y				UNS		
453			SKIM			Y		N					UNS		
454	noncontact H_2O to WWT	Yes	SKIM	LIME/POLY	CLAR			Y		SKIM	HAUL		WWT		WWT
457	1 DAF unit total		DAF	NaOH/POLY	DAF		PRES	Y		SKIM	UNS	WWT	WWT	WWT	
459		Yes		NaOH/POLY	CLAR			Y	Y				WWT	WWT	
471		Yes		NaOH/POLY	CLAR			Y	Y				WWT	WWT	
477			SKIM	NaOH/POLY	SETL	Y		N					UNS		
481	NCA														
483						Y		Y		ACID/SKIM	HAUL	WWT	POTW		
485		Yes	SKIM			Y		Y	Y				UNS		
488	1 DAF unit total	Yes	DAF	NaOH/POLY	DAF		VAC FILT	Y		POLY	RCLM	WWT	POTW		POTW
490			SKIM	NaOH/POLY	SETL	Y		N			HAUL		UNS		
492	noncontact H_2O to WWT 1 DAF unit total		DAF	NaOH/POLY	DAF		PRES	Y		SKIM	UNS	WWT	WWT	WWT	
499	noncontact H_2O to WWT		SKIM			Y		N					WWT	WWT	WWT
502			SKIM			Y		N			HAUL	WWT	WWT		WWT
508		Yes		LIME/POLY	LAM		FILT PRES	Y	Y				WWT		
509						Y		N				WWT	UNS		
511	1 DAF unit total	Yes	DAF	NaOH/POLY	DAF		VAC FILT	Y		POLY	HAUL	WWT	UNS		
515		Yes		NaOH/POLY	CLAR			Y	Y				WWT	WWT	
523						Y		Y	Y				WWT		
524	1 DAF unit total	Yes	DAF	NaOH/POLY	DAF			Y		GRAV	HAUL	WWT	UNS		
*530		Yes	HEAT/SKIM	LIME/POLY	LAM		CENT	Y	Y				WWT		
539	NCA														
541						Y		Y	Y				WWT		
542	1 DAF unit total		DAF	NaOH/POLY/ ALUM	DAF		VAC FILT	N					POTW		
*547	Plant may be shutting down							Y		CEB/DAF	RCLM	WWT	WWT		
548	noncontact H_2O to WWT, 1 DAF unit total		SKIM/ DAF	NaOH	DAF			N					POTW		
550	1 DAF unit total		SKIM/CEB/ DAF	NaOH/POLY	DAF		THICK	UNS					UNS		
555		Yes		NaOH/POLY	CLAR			Y		PRES	HAUL	WWT	WWT	WWT	
557			SKIM			Y		N					POTW		
558	Ammonia for final pH adj., noncontact H_2O to WWT		SKIM			Y		N					WWT	WWT	WWT

TABLE V-13 (Continued)
TREATMENT IN PLACE

		CANWASHER WASTE STREAM						OILY WASTE STREAM							
ID	NOTES	EQUAL	OIL REM	PREC	SOL REM	FIN pH ADJ	SLUDGE DEWAT	SEP	HAUL NO PRE	PRETREAT	OILY FRACTION	H_2O FRACTION	DI	ACTIVATED CARBON BACKWASH	SCRUBBER AND MISC.
	ALUMINUM BASIS MATERIAL														
565			SKIM	LIME/POLY/ NaOH	CLAR		VAC FILT	Y		CEB	RCLM	WWT	WWT		
577		Yes		LIME/POLY	CLAR		VAC FILT	Y		PRES	RCLM	WWT	WWT	WWT	
578		Yes		NaOH/POLY	CLAR		CENT/DRYER	Y		ACID/HEAT	HAUL	WWT	WWT	WWT	
582	1 DAF unit total	Yes	DAF	NaOH/POLY	DAF		VAC FILT	Y		POLY	LAND	WWT	UNS		
588	1 DAF unit total	Yes	DAF	NaOH/POLY	DAF			Y		GRAV	HAUL	WWT	UNS		
604						Y		Y	Y				WWT		
605	noncontact H_2O to WWT	Yes	CEB/SKIM	LIME/POLY	LAM	Y	VAC FILT	Y		SKIM	HAUL	LUBE	WWT		WWT
607		Yes	SKIM			Y		Y		POLY	SOLD	WWT	UNS		
608			SKIM			Y		N					UNS		
613						Y		Y	Y				WWT		
619	noncontact H_2O to WWT, 1 DAF unit total		SKIM/ DAF	NaOH	DAF			N					WWT	WWT	WWT
622	noncontact H_2O to WWT		SKIM			Y		N					UNS	WWT	WWT
626	No WWT							Y	Y				FOTW		
633	1 DAF unit total		DAF	ALUM/KOH/ POLY	DAF			Y		UF	HAUL	WWT	WWT		
642	1 DAF unit total	Yes	DAF	ALUM/LIME/ Cl/NaOH/ PO_4/POLY	DAF		VAC FILT	Y		ACID/GRAV	HAUL	WWT	FOTW		
644	1 DAF unit total		DAF	NaOH/POLY	DAF		PRES	Y		SKIM	UNS	WWT	WWT	WWT	
648		Yes				Y		Y	Y				WWT	WWT	
661	lab sink & fume hood H_2O to WWT			LIME/POLY	LAM		VAC FILT	Y		ACID/SKIM	HAUL	WWT	WWT		WWT
666				NaOH/FeCl/ POLY	SETL/ FILT		FILT PRES	Y	Y				WWT		
667		Yes		NaOH/POLY	CLAR		CENT	Y		ACID/HEAT	SOLD	WWT	WWT	WWT	
671	1 DAF unit total	Yes	PRES/DAF	NaOH/ALUM/ POLY	DAF		FILT PRES	N					WWT		
673						Y		Y	Y				WWT		
675				NaOH	CLAR			Y	Y				WWT		
678		Yes		NaOH/POLY	CLAR			Y	Y				WWT	WWT	
688	1 DAF unit total, scrubber H_2O to FOTW	Yes	DAF	NaOH/POLY	DAF		VAC FILT	Y		POLY	HAUL	WWT	UNS		FOTW
689	NCA														
692		Yes				Y		Y	Y				WWT	WWT	
	STEEL BASIS MATERIAL														
001	1 DAF unit total	Yes	PRES/DAF	POLY/NaOH/ ALUM	DAF		FILT PRES	N							
417	NCA												WWT		
424	No WWT												FOTW		
440	No WWT												UNS		
461								N					UNS		
468						Y		Y	Y				WWT		WWT
479	NCA		SKIM					N			RCLM	FOTW	UNS		
489	NCA														

TABLE V-13 (Continued)
TREATMENT IN PLACE

ID	NOTES	CANWASHER WASTE STREAM						OILY WASTE STREAM							
		EQUAL	OIL REM	PREC	SOL REM	FIN pH ADJ	SLUDGE DEWAT	SEP	HAUL NO PRE	PRETREAT	OILY FRACTION	H_2O FRACTION	DI	ACTIVATED CARBON BACKWASH	SCRUBBER AND MISC.
	STEEL BASIS MATERIAL														
497								Y		SKIM/UF	HAUL	POTW	POTW		
*525				LIME/POLY	CLAR		VAC FILT	Y	Y				UNS		
531	No WWT												UNS		
574	noncontact and scrubber H_2O to POTW 1 DAF unit total	Yes	DAF	NaOH/ALUM/ POLY	DAF/SETL		PRES	Y		NaOH/POLY	RCLM	WWT	POTW		POTW
585	No WWT												POTW		
*587		Yes		LIME/POLY	CLAR		VAC FILT	Y		SKIM	RCLM	LUBE	WWT		
592			SKIM										UNS		
603	No WWT												UNS		
621	Electrodialysis brine							Y		UF	LAND	POTW	POTW	POTW	POTW
631	NCA														
641	1 DAF unit total	Yes	DAF	NaOH/POLY	DAF		VAC FILT	Y		POLY	LAND	WWT	UNS		
655	No WWT												UNS		

KEY

* - Chromium Reduction
ACID - Acid Cracking
CEB - Chemical Emulsion Breaking
CENT - Centrifuge
CLAR - Clarifier
DAF - Dissolved Air Flotation
DI - Deionization Columns Regenerant
DRYER - Sludge Dryer
EQUAL - Equalization
FILT - Filter
FILT PRES - Filter Press
FIN pH ADJ - Final pH Adjustment Before Discharge
GRAV - Gravity Separation
HAUL - Contract Hauled
HAUL NO PRE - Oily Waste Contract Hauled Without Pretreatment
HEAT - Thermal Emulsion Breaking
LAM - Lamella (Inclined Tube Settler)
LAND - Contract Hauled to Landfill
LUBE - Used as Lubricant (Coolant) Make-up
OIL REM - Oil Removal

N - No
NCA - Not Currently Available
POLY - Polymer
POTW - Discharged to Publicly Owned Treatment Works
PREC - Precipitation
PRES - Treatment Operation Present but Unspecified
RCLM - Reclaimed for Use as Fuel
RO - Reverse Osmosis
SCRUBBER AND MISC. - Scrubber Blowdown or Other Miscellaneous Process Wastewaters (Described in NOTES column)
SEP - Separate Treatment of Oily Waste Stream
SETL - Settling Basin
SKIM - Skimming
SLUDGE DEWAT - Sludge Dewatering
SOLD - Sold for Fuel
SOL REM - Solids Removal
THICK - Sludge Thickening
UF - Ultrafiltration
UNS - Unspecified
VAC FILT - Vacuum Filter
WWT - Added to Wastewater Treatment System of Plant
Y - Yes

TABLE V-14
DCP EFFLUENT DATA (mg/l)

Parameter	002	404	413	423	432	434	441	453	454	461
115. Arsenic										
118. Cadmium										
119. Chromium (total)			0.07	0.1	<0.05	<0.5		<0.1		<0.5
120. Copper										
121. Cyanide					<0.005					
122. Lead			0.01			0.01				0.01
123. Mercury										
124. Nickel										
125. Selenium										
126. Silver					<0.02					
127. Thallium										
128. Zinc			0.1			0.13				0.1
Alkalinity										
Aluminum(total)				15						
Aluminum(dissolved)										
Barium										
BOD		350		40	144	43	350	326	95	250-400
Boron										
Calcium										
Chromium(hexavalent)										
Chromium(trivalent)										
Chlorine										
Chlorine Demand										
COD		1,000			356		1,000		420	
DO										
Fluoride								126		
Hardness										
Hexane										
Iron										
Magnesium										
Manganese										
NO_2-N										
NO_3-N										
Oil & Grease	1,278	2,000	168	100		28	2,000	674	70	
Oil & Grease-E										
pH			5.8	6.5	8.6				8.0	7.5-8.5
Phenol					0.24					
Phosphate										
Phosphorus										
Silicon										
Sulfate										
Sulfur										
Surfactants										
TDS									1,550	
Tin										
Titanium										
TKN										
TOC										
TS								1,163		
TSS		400	418	1,100	196	78	400		100	100-250

TABLE V-14 (Continued)
DCP EFFLUENT DATA (mg/l)

Parameter	468	471	477	481	485	488	490	497	502	508
115. Arsenic		<0.05	<0.05							
118. Cadmium	<0.02	<0.02	<0.05	0.021					<0.001	
119. Chromium (total)	<0.04		<0.05	0.128					<0.04	0.14
120. Copper	<0.03		0.1	0.04						0.06
121. Cyanide			<0.05	<0.02						
122. Lead	<0.18		0.3	0.135			<0.01		<0.02	
123. Mercury			<0.005							
124. Nickel	<0.22	0.27	<0.05	0.1						
125. Selenium		<0.05	<0.05							
126. Silver			<0.05							
127. Thallium										
128. Zinc	0.17		1.4	0.21			<0.24	0.15	0.08	0.21
Alkalinity	289.7									
Aluminum(total)	<0.44			93.3						
Aluminum(dissolved)										
Barium			<0.5							
BOD		53	120	192	350	249		27.6		
Boron	<0.25	0.41	<0.5							
Calcium	28									
Chromium(hexavalent)	<0.12							<0.1		
Chromium(trivalent)								<0.1		
Chlorine										
Chlorine Demand										
COD		479	615		1,000	500	2,180			
DO										
Fluoride				89.3					<0.2	
Hardness										
Hexane						220				
Iron	0.72							0.36	0.57	
Magnesium	10.62									
Manganese	<0.10	1.53	0.12							
NO_2-N										
NO_3-N										
Oil & Grease	12.3	16	125	93.3	2,000		480		120	
Oil & Grease-E				90.0						
pH	8.0	6.25	6.9					7.9	5.5	4.7
Phenol										
Phosphate				19.67						
Phosphorus										
Silicon	12.52									
Sulfate	40.7									
Sulfur										
Surfactants										
TDS	894.5									
Tin	3.90									
Titanium	<0.50									
TKN										
TOC										
TS	926.4									
TSS	31.9		293	346	400	189	900	32.8	293	

TABLE V-14 (Continued)
DCP EFFLUENT DATA (mg/l)

Parameter	509	511	523	524	525	530	531	541	547	565
115. Arsenic		<0.05								
118. Cadmium		<0.01								<0.06
119. Chromium (total)	<0.04	0.07	<0.5				0.06	<0.5	1.7	<0.04
120. Copper	<0.04									0.14
121. Cyanide										
122. Lead		<0.2	0.01					0.01		<0.1
123. Mercury		<0.001								
124. Nickel										0.05
125. Selenium		<0.1								
126. Silver		<0.05								
127. Thallium										
128. Zinc	0.05		0.1					0.1		<0.03
Alkalinity					229					
Aluminum(total)									68	
Aluminum(dissolved)										
Barium		<0.3								
BOD		61-180	<100	350	79			43	98	
Boron										
Calcium										
Chromium(hexavalent)						<0.05			4.6	
Chromium(trivalent)										
Chlorine					107					
Chlorine Demand										
COD		370-830		1,000		500-600	180			
DO										
Fluoride	20-30					10-26				20-30
Hardness					884					
Hexane		32-43								
Iron							0.93			
Magnesium										
Manganese										
NO_2-N					2.4					
NO_3-N					0.04					
Oil & Grease	270		<50	2,000		$46-10^3$	15	28	79	
Oil & Grease-E						<1-8				32
pH	6.7				8.4		7.5		5.6	7.14
Phenol										
Phosphate		0.08-0.13								
Phosphorus					1.99					
Silicon										
Sulfate										
Sulfur					27.5					
Surfactants										
TDS					2,122					
Tin										
Titanium										
TKN					8.26					
TOC						110-128				
TS										
TSS	950		<100	400	25	20-500	34	78	124	54

TABLE V-14 (Continued)
DCP EFFLUENT DATA (mg/l)

Parameter	574	577	578	582	585	587	588	604	605	607
115. Arsenic										
118. Cadmium			<0.01							<0.025
119. Chromium (total)			<0.05			0.14		<0.5		0.15
120. Copper			0.01							<0.05
121. Cyanide			0.49							
122. Lead			<0.2					0.01		<0.1
123. Mercury			0.45							
124. Nickel			<0.5							<0.1
125. Selenium										
126. Silver										
127. Thallium		0.6								
128. Zinc			0.02					0.1		0.4
Alkalinity										
Aluminum(total)		0.51							2.88	
Aluminum(dissolved)										
Barium										
BOD	150						350	50-60		240
Boron										
Calcium		160.3								
Chromium(hexavalent)										
Chromium(trivalent)										
Chlorine										
Chlorine Demand	100									
COD	500	280	1,000		584		1,000			700
DO								6.5-8.0		
Fluoride		1.2								
Hardness										
Hexane				30						
Iron										
Magnesium										
Manganese										
NO_2-N										
NO_3-N										
Oil & Grease			17				2,000	15-40		
Oil & Grease-E									0.4	
pH		7.1			6.5			6.9-7.4	7.7	
Phenol										
Phosphate	25									
Phosphorus										
Silicon										
Sulfate										
Sulfur										
Surfactants										
TDS										
Tin										
Titanium										
TKN										
TOC									95.4	
TS										
TSS	100		6		62		400	275-375	9	259

TABLE V-14 (Continued)
DCP EFFLUENT DATA (mg/l)

Parameter	608	613	621	626	666	667	671	675	688
115. Arsenic									
118. Cadmium									
119. Chromium (total)		<0.5		<0.5	<0.5			<0.5	
120. Copper									
121. Cyanide									
122. Lead		0.01		0.01	0.01			0.01	
123. Mercury									
124. Nickel									
125. Selenium									
126. Silver									
127. Thallium									
128. Zinc		0.1		0.1	0.1			0.1	
Alkalinity									
Aluminum(total)		15			2-4		<2.0	3.0	
Aluminum(dissolved)					1-2			0.5	
Barium									
BOD	59	43		46	35	114		8.4	400
Boron									
Calcium									
Chromium(hexavalent)									
Chromium(trivalent)									
Chlorine									
Chlorine Demand									
COD	823		538						1,500
DO									
Fluoride									
Hardness									
Hexane									
Iron									
Magnesium									
Manganese									
NO_2-N									
NO_3-N									
Oil & Grease	143	<100		107	10	66			100
Oil & Grease-E									
pH					7.8-8.5			8.0	
Phenol									
Phosphate									
Phosphorus									
Silicon									
Sulfate									
Sulfur									
Surfactants	0.05								
TDS									
Tin									
Titanium									
TKN						3.6			
TOC									
TS	928								
TSS	116	78	62	120	20	14		15.0	

TABLE V-15
SAMPLED PLANTS EFFLUENT DATA (mg/1)
ALUMINUM BASIS MATERIAL[1]

Plant ID (day)	488(1)	488(2)	488(3)	515(1)	515(2)	515(3)	557(1)	557(2)	557(3)	565(1)	565(2)	565(3)
Flow (1/day)	164,308	142,506	131,605	185,314	185,314	185,314	261,619	261,619	261,619	237,092	277,426	286,692
Parameter												
4. Benzene	ND	ND	ND	*	ND	*	ND	ND	ND	NA	NA	NA
11. 1,1,1,-Trichloroethane	0.020	*	*	0.061	0.022	0.031	0.770	1.50	*	NA	NA	NA
13. 1,1-Dichloroethane	ND	ND	ND	ND	ND	ND	ND	*	ND	NA	NA	NA
22. Parachlorometa cresol	ND	ND	ND	ND	0.038	ND	ND	ND	ND	NA	NA	NA
23. Chloroform	ND	ND	ND	*	0.012	0.015	ND	ND	ND	NA	NA	NA
30. 1,2-Trans-dichloroethylene	ND	ND	ND	ND	ND	ND	0.040	ND	ND	NA	NA	NA
38. Ethylbenzene	ND	ND	ND	*	0.017	0.014	ND	ND	ND	NA	NA	NA
44. Methylene chloride	0.020	*	*	0.150	0.074	0.203	*	ND	*	NA	NA	NA
48. Dichlorobromomethane	ND	ND	ND	ND	ND	*	ND	ND	ND	NA	NA	NA
51. Chlorodibromomethane	ND	ND	ND	*	ND	ND	ND	ND	ND	NA	NA	NA
55. Naphthalene	ND	ND	ND	ND	0.037	0.057	ND	ND	ND	NA	NA	NA
65. Phenol	ND	0.050	0.060	*	*	*	ND	ND	ND	NA	NA	NA
66. Bis(2-ethylhexyl)phthalate	ND	0.050	0.480	0.500	0.850	0.461	0.040	0.020	ND	NA	NA	NA
68. Di-n-butyl phthalate	ND	ND	ND	0.300	0.505	ND	ND	ND	ND	NA	NA	NA
85. Tetrachloroethylene	ND	ND	ND	*	ND	ND	ND	ND	ND	NA	NA	NA
86. Toluene	*	*	ND	0.023	0.018	0.036	*	*	*	NA	NA	NA
87. Trichloroethylene	ND	ND	ND	*	ND	*	ND	ND	ND	NA	NA	NA
92. 4,4-DDT	ND	ND	ND	**	NA	NA	ND	ND	ND	NA	NA	NA
93. 4,4-DDE	ND	ND	ND	**	NA	NA	ND	ND	ND	NA	NA	NA
98. Endrin	ND	ND	ND	**	NA	NA	ND	ND	ND	NA	NA	NA
100. Heptachlor	ND	ND	ND	**	NA	NA	ND	ND	ND	NA	NA	NA
102. Alpha-BHC	ND	ND	ND	**	NA	NA	ND	ND	ND	NA	NA	NA
103. Beta-BHC	ND	ND	ND	**	NA	NA	ND	ND	ND	NA	NA	NA
104. Gamma-BHC	ND	ND	ND	**	NA	NA	ND	ND	ND	NA	NA	NA
105. Delta-BHC	ND	ND	ND	ND	NA	NA	ND	ND	ND	NA	NA	NA
106. PCB-1242	ND	ND	ND	ND	NA	NA	ND	ND	ND	NA	NA	NA
107. PCB-1254	ND	ND	ND	**	NA	NA	ND	ND	ND	NA	NA	NA
108. PCB-1221	ND	ND	ND	ND	NA	NA	ND	ND	ND	NA	NA	NA
109. PCB-1232	ND	ND	ND	ND	NA	NA	ND	ND	ND	NA	NA	NA
110. PCB-1248	ND	ND	ND	**	NA	NA	ND	ND	ND	NA	NA	NA

* Possibly detected but <0.010 mg/1.
** Possibly detected but ≤0.005 mg/1.
NA Not analyzed.
ND Not detected.
[1] Effluent Data for Steel Basis Material (Plant 655) is the same as raw waste.

TABLE V-15(Continued)
SAMPLED PLANTS EFFLUENT DATA (mg/l)
ALUMINUM BASIS MATERIAL

Plant ID (day)	488(1)	488(2)	488(3)	515(1)	515(2)	515(3)	557(1)	557(2)	557(3)	565(1)	565(2)	565(3)
Parameter												
111. PCB-1260	ND	ND	ND	ND	NA	NA	ND	ND	ND	NA	NA	NA
115. Arsenic	0.210	0.081	0.160	ND	ND	ND	0.0041	0.0045	0.011	ND	ND	ND
117. Beryllium	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA	NA
118. Cadmium	0.0093	0.013	ND	ND	ND	ND	0.0026	0.003	0.0035	ND	ND	ND
119. Chromium	0.170	0.130	0.220	ND	ND	ND	0.021	0.013	0.019	0.15	0.12	0.039
120. Copper	0.070	ND	0.083	ND	0.02	0.02	0.070	0.024	0.022	ND	ND	0.016
121. Cyanide	NA	0.02	ND	0.110	0.049	0.027	ND	ND	ND	ND	0.018	ND
122. Lead	ND	0.054	0.004	ND	ND	ND	0.028	0.018	0.036	ND	ND	ND
123. Mercury	0.0022	0.0042	ND	ND	ND	ND	0.0008	0.0004	0.0009	ND	ND	ND
124. Nickel	0.026	0.021	0.130	0.19	0.05	0.02	0.003	ND	ND	ND	ND	ND
128. Zinc	3.2	1.60	5.90	0.08	0.05	0.05	0.180	0.110	0.140	0.015	0.028	0.013
Aluminum	770	250	570	79	4.6	NA	14	15	18	NA	NA	NA
Calcium	56	61.0	66	NA	NA	NA	62.0	62.0	60.0	NA	NA	NA
COD	8,550	1,880	6,640	1380	1860	2080	500	317	739	NA	NA	NA
Fluoride	NA	53	61	NA	NA	NA	NA	NA	NA	23.0	27.0	22.0
Iron	1.3	2.0	1.7	0.28	0.49	0.45	0.140	0.290	0.300	0.087	0.067	0.067
Magnesium	11.9	13.5	15.0	NA	NA	NA	16.3	15.9	16.2	NA	NA	NA
Manganese	NA	0.49	0.750	3.8	1.6	1.4	0.310	0.330	0.340	NA	NA	NA
Phenols	0.103	NA	0.014	0.010	0.008	0.010	0.059	0.014	0.007	0.010	0.019	0.005
Phosphorus	NA	NA	NA	NA	NA	NA	NA	NA	NA	1.46	0.40	0.41
Sulfate	2,800	1,500	2,980	570	570	NA	NA	NA	NA	NA	NA	NA
TOC	435	180	1,165	NA	NA	NA	87	91	76	NA	NA	NA
Oil & Grease	780	3,930	490	NA	NA	NA	222	385	326	25	12	16
TSS	55,000	1,210	4,720	60	56	159	108	104	125	13	14	23
pH	8.4	8.4	8.7	5.9	6.9	7.3	6.1	6.4	NA	7.9	7.7	8.4
Temperature, C	24	31	31	28.5	28	29	26	29	NA	28	28	29

TABLE V-16
SAMPLED PLANTS EFFLUENT DATA (mg/1000 cans)
ALUMINUM BASIS MATERIAL[1]

Plant ID (Day)	488(1)	488(2)	488(3)	515(1)	515(2)	515(3)	557(1)	557(2)	557(3)	565(3)	565(2)	565(1)
Flow (1/1000 cans)	116.2	104.6	104.1	85.7	77.7	63.2	277.3	281.8	264.5	132.4	154.9	160.1
Parameter												
4. Benzene	ND	ND	ND	0.0	ND	0.0	ND	ND	ND	NA	NA	NA
11. 1,1,1-Trichloroethane	2.324	0.0	0.0	5.23	1.709	1.959	215.5	ND	0.0	NA	NA	NA
13. 1,1,-Dichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	NA	NA	NA
22. Parachlorometa cresol	ND	ND	ND	ND	0.0	ND	ND	ND	ND	NA	NA	NA
23. Chloroform	ND	ND	ND	0.0	0.932	0.948	ND	ND	ND	ND	NA	NA
30. 1,2-Trans-dichloroethylene	ND	ND	ND	ND	ND	ND	11.09	ND	ND	NA	NA	NA
38. Ethylbenzene	ND	ND	ND	0.0	1.321	0.885	ND	ND	ND	NA	NA	NA
44. Methylene chloride	2.324	0.0	0.0	12.86	5.75	12.83	0.0	ND	ND	NA	NA	NA
48. Dichlorobromomethane	ND	ND	ND	ND	ND	0.0	ND	ND	ND	NA	NA	NA
51. Chlorodibromomethane	ND	ND	ND	0.0	ND	ND	ND	ND	ND	NA	NA	NA
55. Naphthalene	ND	ND	ND	ND	2.875	3.602	ND	ND	ND	NA	NA	NA
65. Phenol	ND	5.23	6.25	0.0	0.0	0.0	ND	ND	ND	NA	NA	NA
66. Bis(2-ethylhexyl)phthalate	ND	5.23	49.97	42.85	66.0	29.13	11.09	ND	ND	NA	NA	NA
68. Di-n-butyl phthalate	ND	ND	ND	25.1	39.24	ND	ND	ND	ND	NA	NA	NA
85. Tetrachloroethylene	ND	ND	ND	0.0	ND	ND	ND	ND	ND	NA	NA	NA
86. Toluene	0.0	0.0	ND	1.971	1.399	2.275	0.0	ND	0.0	NA	NA	NA
87. Trichloroethylene	ND	ND	ND	0.0	ND	0.0	ND	ND	ND	NA	NA	NA
92. 4,4-DDT	ND	ND	ND	0.0	NA	NA	ND	ND	ND	NA	NA	NA
93. 4,4-DDE	ND	ND	ND	0.0	NA	NA	ND	ND	ND	NA	NA	NA
98. Endrin	ND	ND	ND	0.0	NA	NA	ND	ND	ND	NA	NA	NA
100. Heptachlor	ND	ND	ND	0.0	NA	NA	ND	ND	ND	NA	NA	NA
102. Alpha-BHC	ND	ND	ND	0.0	NA	NA	ND	ND	ND	NA	NA	NA
103. Beta-BHC	ND	ND	ND	0.0	NA	NA	ND	ND	ND	NA	NA	NA
104. Gamma-BHC	ND	ND	ND	0.0	NA	NA	ND	ND	ND	NA	NA	NA
105. Delta-BHC	ND	ND	ND	ND	NA	NA	ND	ND	ND	NA	NA	NA
106. PCB-1242	ND	ND	ND	ND	NA	NA	ND	ND	ND	NA	NA	NA
107. PCB-1254	ND	ND	ND	0.0	NA	NA	ND	ND	ND	NA	NA	NA
108. PCB-1221	ND	ND	ND	ND	NA	NA	ND	ND	ND	NA	NA	NA
109. PCB-1232	ND	ND	ND	ND	NA	NA	ND	ND	ND	NA	NA	NA
110. PCB-1248	ND	ND	ND	0.0	NA	NA	ND	ND	ND	NA	NA	NA

ND Not Detected
NA Not Analyzed
[1] Effluent Data for Steel Basis Material (Plant 655) is the same as raw waste.

TABLE V-16 (Continued)
SAMPLED PLANTS EFFLUENT DATA (mg/1000 cans)
ALUMINUM BASIS MATERIAL

Plant ID (Day)	488(1)	488(2)	488(3)	515(1)	515(2)	515(3)	557(1)	557(2)	557(3)	565(2)	565(3)	565(1)
Flow (1/1000 cans)	116.2	104.6	104.1	85.7	77.7	63.2	277.3	281.8	264.5	132.4	154.9	160.1
Parameter												
111. PCB-1260	ND	ND	ND	ND	NA	NA	ND	ND	NA	ND	NA	NA
115. Arsenic	24.40	8.473	16.65	ND	ND	ND	1.137	1.268	ND	2.910	ND	ND
117. Beryllium	ND	ND	ND	ND	ND	ND	ND	ND	NA	ND	NA	NA
118. Cadmium	1.081	1.36	0.0937	ND	ND	ND	0.721	0.845	ND	0.926	ND	ND
119. Chromium	19.75	13.6	22.9	ND	ND	ND	5.82	3.66	18.59	5.024	19.86	6.244
120. Copper	8.134	ND	8.64	ND	1.554	1.264	19.41	6.76	ND	5.82	ND	2.562
121. Cyanide	ND	2.092	ND	9.427	3.807	1.706	ND	ND	2.79	ND	ND	ND
122. Lead	0.116	5.648	0.416	ND	ND	ND	7.76	5.07	ND	9.52	ND	ND
123. Mercury	ND	0.439	ND	ND	ND	ND	0.2218	0.1127	ND	0.2381	ND	ND
124. Nickel	3.021	2.196	13.53	16.28	3.885	1.264	0.832	ND	ND	ND	ND	ND
128. Zinc	371.8	167.4	614.19	6.856	3.885	3.16	49.9	31.00	4.34	37.02	1.986	2.08
Aluminum	89,474	26,150	59,337	6,770	357.4	NA	3,882	4,226	NA	4,760	NA	NA
Calcium	6,507	6,381	6,870	NA	NA	NA	17,193	17,465	NA	15,864	NA	NA
COD	993,510	196,648	691,224	118,266	144,522	131,456	138,650	89,300	NA	195,392	NA	NA
Fluoride	NA	5,543	6,350	NA	NA	NA	NA	NA	4,182	NA	3,045	3,522
Iron	151.1	209.2	176.97	23,996	38.07	28.44	38.8	81.7	10.38	79.4	11.52	10.73
Magnesium	1,382	1,412	1,561	NA	NA	NA	4,520	4,479	NA	4,283	NA	NA
Manganese	ND	51.25	78.08	325.7	124.3	88.48	86.0	93.0	NA	89.9	NA	NA
Phenols	11.97	NA	1.457	0.857	0.622	0.632	16.36	3.95	2.943	1.851	1.324	ND
Phosphorus	NA	NA	NA	NA	NA	NA	NA	NA	61.96	NA	19.3	65.64
Sulfate	325,360	156,900	310,218	48.85	44,289	NA	NA	NA	NA	NA	NA	NA
TOC	50,547	18,828	121,276	NA	NA	NA	24,125	25,635	NA	20,094	NA	NA
Oil & Grease	90,636	411,078	51,009	NA	NA	NA	61,561	108,455	1,858	86,194	3,310	2,561
TSS	6,391,000	126,566	491,352	5,142	4,351	10,048	29,950	29,927	2,168	33,050	1,721	3,682
pH	8.4	8.6	8.7	5.9	6.9	7.3	6.1	6.4	7.7	NA	8.3	8.4
Temperature, C	24	31	31	28.5	28	29	26	29	28	NA	28	29

TABLE V-17
CMI & USBA EFFLUENT DATA (mg/l)*

Parameter	404(1)	404(2)	404(3)	488(1)	488(2)	488(3)	511(1)	511(2)	511(3)
119. Chromium	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
128. Zinc	0.10	0.10	0.10	0.20	0.20	0.20	0.10	0.10	0.10
Aluminum	17.10	6.80	14.20	29.40	23.10	33.9	17.00	16.00	15.00
Fluoride	35.00	28.50	38.00	74.00	76.00	100.00	40.00	45.00	45.00
Phosphorus	0.60	0.60	0.10	0.20	0.20	0.50	0.10	1.00	1.30
pH	7.20	7.20	7.20	NA	7.43	6.81	6.70	6.60	6.50
TSS	6.60	4.60	47.30	12.00	101.00	64.00	36.00	19.00	4.00
O&G-A	54.40	48.60	45.70	20.00	16.00	18.50	37.60	37.40	42.80
O&G-E	12.90	19.40	14.10	3.90	1.70	4.70	4.10	1.30	2.60

Parameter	530(1)	530(2)	530(3)	542(1)	542(2)	542(3)	550(1)	550(2)	550(3)
119. Chromium	0.30	0.20	0.10	0.10	0.10	0.10	0.40	0.10	0.10
128. Zinc	0.10	0.10	0.10	0.20	0.10	0.10	0.50	0.10	0.10
Aluminum	1.70	1.60	1.50	8.80	13.10	8.90	82.50	9.30	13.80
Fluoride	17.70	22.80	22.80	16.50	24.00	14.50	115.00	77.00	68.00
Phosphorus	2.00	2.00	2.30	3.00	1.00	0.00	0.10	0.10	0.10
pH	8.10	7.80	8.00	5.70	7.00	6.50	NA	NA	NA
TSS	4.50	8.50	7.50	42.50	19.00	20.50	233.00	38.00	48.00
O&G-A	40.70	58.70	84.20	176.00	73.90	35.00	29.80	39.50	29.60
O&G-E	1.70	4.90	14.20	87.20	18.10	12.70	2.10	4.30	0.40

Parameter	557(1)	557(2)	557(3)	565(1)	565(2)	565(3)	578(1)	578(2)	578(3)
119. Chromium	0.10	0.10	0.10	0.02	0.02	0.02	0.10	0.10	0.10
128. Zinc	0.30	0.20	0.20	0.01	0.01	0.01	0.10	0.10	0.10
Aluminum	22.00	16.30	12.40	7.00	5.00	3.00	2.40	3.70	14.00
Fluoride	37.00	33.00	22.80	28.00	23.00	29.00	55.00	66.00	62.00
Phosphorus	0.10	0.60	0.60	1.82	1.47	1.71	0.60	1.70	0.10
pH	7.33	7.30	6.74	6.30	6.90	5.90	8.40	8.40	8.70
TSS	47.00	10.80	10.80	43.00	18.00	13.00	6.00	6.00	15.00
O&G-A	NA	NA	NA	94.00	24.00	28.00	30.80	21.80	38.80
O&G-E	NA	NA	NA	46.00	8.00	7.00	0.50	0.90	1.60

*Data recorded as submitted by CMI & USBA.

NA Not Available

TABLE V-17 (Continued)
CMI & USBA EFFLUENT DATA (mg/1)*

Parameter	605(1)	605(2)	605(3)	633(1)	633(2)	633(3)	666(1)	666(2)	666(3)
119. Chromium	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
128. Zinc	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Aluminum	2.50	8.20	13.90	11.00	3.10	3.70	2.90	1.80	8.20
Fluoride	30.00	38.00	33.00	11.40	6.90	6.00	61.00	53.00	49.00
Phosphorus	1.10	1.60	3.20	0.10	0.70	0.60	0.50	1.40	1.40
pH	7.80	7.60	7.50	6.50	6.60	6.70	7.70	7.60	NA
TSS	4.00	2.40	2.40	6.60	8.60	12.40	31.00	44.00	71.50
O&G-A	43.40	52.20	62.60	36.90	37.20	32.80	18.30	20.20	NA
O&G-E	3.00	2.50	2.50	7.10	6.00	6.20	3.00	5.90	NA

Parameter	667(1)	667(2)	667(3)	688(1)	688(2)	688(3)
119. Chromium	0.10	0.10	0.10	0.10	0.10	0.10
128. Zinc	0.10	0.10	0.10	0.10	0.10	0.10
Aluminum	7.40	5.90	7.20	14.00	15.00	13.00
Fluoride	43.00	31.00	38.00	83.00	76.00	54.00
Phosphorus	0.10	0.10	0.10	0.10	0.10	0.10
pH	7.30	7.20	7.00	8.00	4.80	8.80
TSS	38.50	32.00	12.00	37.00	34.00	22.50
O&G-A	71.70	85.40	46.30	NA	63.10	100.00
O&G-E	45.00	39.00	25.00	NA	8.30	2.20

* Data recorded as submitted by CMI & USBA

NA Not Available

TABLE V-18
CMI & USBA EFFLUENT DATA (mg/1000 cans)*

Plant ID(day)	404(1)	404(2)	404(3)	488(1)	488(2)	488(3)	511(1)	511(2)	511(3)
Flow (1/1000 cans)**	295.9	336.1	247.9	79.0	72.0	75.0	111.6	114.0	116.4
Parameter									
119. Chromium	29.59	33.61	24.79	7.90	7.20	7.50	11.16	11.40	11.64
128. Zinc	29.59	33.61	24.79	15.80	14.40	15.00	11.16	11.40	11.64
Aluminum	5,059.89	2,285.48	3,520.18	2,322.60	1,663.20	2,542.50	1,897.20	1,824.00	1,746.00
Flouride	10,356.50	9,578.85	9,420.20	5,846.00	5,472.00	7,500.00	4,464.00	5,130.00	5,238.00
Phosphorus	177.54	201.66	24.79	15.80	14.40	37.50	11.16	114.00	151.30
TSS	1,952.94	1,546.06	11,725.70	948.00	7,272.00	4,800.00	4,017.60	2,166.00	465.60
O&G-A	16,096.96	16,334.50	11,329.00	1,580.00	1,152.00	1,387.50	4,196.16	4,263.60	4,981.90
O&G-E	3,817.11	6,520.34	3,495.39	308.10	122.40	352.50	457.56	148.20	302.64
pH	7.20	7.20	7.20	NA	7.43	6.81	6.70	6.60	6.50

Parameter	530(1) 92.6	530(2) 98.8	530(3) 104.4	542(1) 215.4	542(2) 220.5	542(3) 205.1	550(1) 92.0	550(2) 92.0	550(3) 92.0
119. Chromium	27.78	19.76	10.44	21.54	22.05	20.51	36.80	9.20	9.20
128. Zinc	9.26	9.88	10.44	43.08	22.05	20.51	46.00	9.20	9.20
Aluminum	157.42	158.08	156.60	1,895.52	2,888.55	1,825.39	7,590.00	855.60	1,269.60
Fluoride	1,639.02	2,252.64	2,380.32	3,554.10	5,292.00	2,973.95	10,580.00	7,084.00	6,256.00
Phosphorus	185.20	197.60	240.12	646.20	220.50	0.00	9.20	9.20	9.20
TSS	416.70	839.80	783.00	9,154.50	4,189.50	4,204.55	21,436.00	3,496.00	4,416.00
O&G-A	3,768.82	5,799.56	8,790.48	37,910.40	16,294.95	7,178.50	2,741.60	3,634.00	2,723.20
O&G-E	157.42	484.12	1,482.48	18,782.88	3,991.05	2,604.77	193.20	395.60	36.80
pH	8.10	7.80	8.00	5.70	7.00	6.50	NA	NA	NA

Parameter	557(1) 354.6	557(2) 311.8	557(3) 362.2	565(1) 187.5	565(2) 210.1	565(3) 230.8	578(1) 142.4	578(2) 130.8	578(3) 141.0
119. Chromium	35.46	31.18	36.22	3.75	4.20	4.62	14.24	13.08	14.10
128. Zinc	106.38	62.36	72.44	1.88	2.10	2.31	14.24	13.08	14.10
Aluminum	7,801.20	5,082.34	4,491.28	1,312.50	1,050.50	692.40	341.76	483.96	1,974.00
Fluoride	13,120.20	10,289.40	8,258.16	5,250.00	4,832.30	6,693.20	7,832.00	8,632.80	8,742.00
Phosphorus	35.46	187.08	217.32	341.25	308.85	394.67	85.44	222.36	14.10
TSS	16,666.20	3,367.44	3,911.76	8,062.50	3,781.80	3,000.40	854.46	784.80	2,115.00
O&G-A	NA	NA	NA	17,625.00	5,042.40	6,462.40	4,385.92	2,851.44	5,470.00
O&G-E	NA	NA	NA	8,625.00	1,680.80	1,615.60	71.20	117.72	225.60
pH	7.33	7.30	6.74	6.30	6.90	5.90	8.40	8.40	8.70

*Data recorded as submitted by CMI & USBA
**Based on flow and production data provided by CMI & USBA for each sampling day. See also Table V-6.

NA Not Available

Table V-18 (Continued)
CMI & USBA EFFLUENT DATA (mg/1000 cans)*

	605(1)	605(2)	605(3)	633(1)	633(2)	633(3)	666(1)	666(2)	666(3)
Parameter	175.2	153.3	164.4	278.9	222.8	258.7	133.0	99.0	126.0
119. Chromium	17.52	15.33	16.44	27.89	22.28	25.87	13.30	9.90	12.60
128. Zinc	17.52	15.33	16.44	27.89	22.28	25.87	13.30	9.90	12.60
Aluminum	438.00	1,257.06	2,285.16	3,067.90	690.68	957.19	385.70	178.20	1,033.20
Fluoride	5,256.00	5,825.40	5,425.20	3,179.46	1,537.32	1,552.20	8,113.00	5,247.00	6,174.00
Phosphorus	192.72	245.28	526.08	27.89	155.96	155.22	66.50	138.60	176.00
TSS	700.80	367.92	394.56	1,840.74	1,916.08	3,207.88	4,123.00	4,356.00	9,009.00
O&G-A	7,603.68	8,002.26	10,291.40	10,291.41	8,288.16	8,485.36	2,433.90	1,999.80	NA
O&G-E	525.60	383.25	411.00	1,980.19	1,336.80	1,603.94	399.00	584.10	NA
pH	7.80	7.60	7.50	6.50	6.60	6.70	7.70	7.60	NA

	667(1)	667(2)	667(3)	688(1)	688(2)	688(3)
Parameter	61.6	69.6	132.4	65.5	69.2	72.6
119. Chromium	6.16	6.96	13.24	6.55	6.92	7.26
128. Zinc	6.16	6.96	13.24	6.55	6.92	7.26
Aluminum	455.84	410.64	953.28	917.00	1,038.00	943.80
Fluoride	2,648.80	2,157.60	5,031.20	5,436.50	5,259.20	3,920.40
Phosphorus	6.16	6.96	13.24	6.55	6.92	7.26
TSS	2,371.60	2,227.20	1,588.80	2,423.50	2,352.80	1,633.50
O&G-A	4,416.72	5,943.84	6,130.12	NA	4,366.52	7,260.00
O&G-E	2,772.00	2,714.40	3,310.00	NA	574.36	159.72
pH	7.30	7.20	7.00	8.00	4.80	8.80

*Data recorded as submitted by CMI & USBA
**Based on flow and production data provided by CMI & USBA for each sampling day. See also Table V-6.

NA Not Available

TABLE V-19
POSTPROPOSAL EPA SAMPLED PLANTS EFFLUENT DATA (mg/1)

Parameter	511(1)	530(1)	542(2)	578(2)	605(1)	688(1)
18. Bis(2-chloroethyl)ether	ND	ND	0.018	*	NA	NA
23. Chloroform	*	*	0.012	*	NA	NA
30. 1,2-Trans-dichloroethylene	ND	ND	*	ND	NA	NA
44. Methylene chloride	ND	0.154	*	0.014	NA	NA
47. Bromoform	*	ND	ND	ND	NA	NA
64. Pentachlorophenol	0.030	ND	ND	ND	NA	NA
65. Phenol	ND	ND	*	*	NA	NA
66. Bis(2-ethylhexyl)phthalate	0.035	*	0.011	ND	NA	NA
67. Butyl benzyl phthalate	ND	ND	0.186	ND	NA	NA
68. Di-n-butyl phthalate	ND	*	ND	ND	NA	NA
85. Tetrachloroethylene	ND	ND	0.018	ND	NA	NA
86. Toluene	0.017	ND	*	ND	NA	NA
117. Beryllium	ND	ND	ND	ND	ND	ND
118. Cadmium	ND	ND	ND	ND	ND	ND
119. Chromium	ND	0.080	0.120	ND	ND	ND
120. Copper	ND	ND	ND	ND	ND	ND
122. Lead	0.100	ND	ND	0.600	ND	ND
124. Nickel	0.100	ND	0.100	ND	ND	ND
128. Zinc	ND	ND	0.040	ND	0.020	ND
Aluminum	16.200	2.600	64.400	2.600	1.500	7.300
Barium	ND	ND	ND	ND	ND	ND
Boron	0.200	ND	0.500	0.200	3.500	0.700
Calcium	4.700	480.000	2.8200	45.100	143.000	44.600
Cobalt	ND	ND	ND	ND	ND	ND
Fluoride	98.000	42.000	32.000	60.000	23.000	96.000
Iron	0.150	0.050	2.050	0.100	0.100	ND
Magnesium	4.200	14.700	8.700	21.000	15.000	16.800
Manganese	0.950	0.100	0.200	0.350	0.200	0.150
Molybdenum	ND	ND	ND	ND	ND	ND
Phosphorus	0.110	0.130	0.130	0.040	0.090	0.070
Sodium	400.000	70.4	502.000	263.000	30.800	748.000
Tin	ND	ND	ND	ND	ND	ND
Titanium	ND	ND	ND	ND	ND	ND
Vanadium	ND	ND	ND	ND	ND	ND
Yttrium	ND	ND	ND	ND	ND	ND

* Possibly detected but <0.010 mg/1.

NA Not Analyzed
ND Not Detected

(1) Sample collected in plastic container
(2) Sample collected in glass container

TABLE V-20
POSTPROPOSAL EPA SAMPLED PLANTS EFFLUENT DATA (mg/1000 Cans)

Plant ID	511	530	542	578	605	688
Flow, (1/1000 cans)*	125.4	95.0	119.9	146.7	174.9	68.1
Parameter						
18. Bis(2-chloroethyl)ether	ND	ND	2.16	0.00	NA	NA
23. Chloroform	0.00	0.00	1.44	0.00	NA	NA
30. 1,2-Trans-dichloroethylene	ND	ND	0.00	ND	NA	NA
44. Methylene chloride	ND	14.63	0.00	2.05	NA	NA
47. Bromoform	0.00	ND	ND	ND	NA	NA
64. Pentachlorophenol	3.76	ND	ND	ND	NA	NA
65. Phenol	ND	ND	0.00	0.00	NA	NA
66. Bis(2-ethylhexyl) phthalate	4.39	0.00	1.32	ND	NA	NA
67. Butyl benzyl phthalate	ND	ND	22.30	ND	NA	NA
68. Di-n-butyl phthalate	ND	0.00	ND	ND	NA	NA
85. Tetrachloroethylene	ND	ND	2.16	ND	NA	NA
86. Toluene	2.13	ND	0.00	ND	NA	NA
117. Beryllium	ND	ND	ND	ND	ND	ND
118. Cadmium	ND	ND	ND	ND	ND	ND
119. Chromium	ND	7.60	14.39	ND	ND	ND
120. Copper	ND	ND	ND	ND	ND	ND
122. Lead	12.54	ND	ND	88.02	ND	ND
124. Nickel	12.54	ND	11.99	ND	ND	ND
128. Zinc	ND	ND	4.80	ND	3.50	ND
Aluminum	2,031.48	247.00	7,721.56	381.42	262.35	497.13
Barium	ND	ND	ND	ND	ND	ND
Boron	25.08	ND	59.95	29.34	612.15	47.67
Calcium	589.38	45,600.00	3,381.18	6,616.17	25,010.70	3,037.26
Cobalt	ND	ND	ND	ND	ND	ND
Fluoride	12,289.20	3,990.00	3,836.80	8,802.00	4,022.70	6,537.60
Iron	18.81	4.75	245.80	14.67	17.49	ND
Magnesium	526.68	1,396.50	1,043.13	3,080.70	2,623.50	1,144.08
Manganese	119.13	9.50	23.98	51.34	34.98	10.22
Molybdenum	ND	ND	ND	ND	ND	ND
Phosphorus	13.79	12.35	15.59	5.87	15.74	4.77
Sodium	50,160.00	6,688.00	60,189.80	38,582.10	5,386.92	50,938.80
Tin	ND	ND	ND	ND	ND	ND
Titanium	ND	ND	ND	ND	ND	ND
Vanadium	ND	ND	ND	ND	ND	ND
Yttrium	ND	ND	ND	ND	ND	ND

*Based on flow and production data presented in Table V-2

NA Not Analyzed
ND Not Detected

TABLE V-21
REYNOLDS ALUMINUM COMPANY EFFLUENT DATA (mg/1)*

Parameter	Plant A 1	Plant A 2	Plant A 3	Plant B 1	Plant B 2	Plant B 3
11. 1,1,1-Trichloroethane	0.0030(1)	0.0041(1)	0.0028(1)	0.0099(2)	0.0972(2)	0.0060(2)
13. 1,1-Dichloroethane(2)	0.0023	ND	ND	ND	0.0180	ND
18. Bis(2-chloroethyl)ether (3)	ND	ND	ND	ND	ND	ND
44. Methylene chloride (2)	0.0052	0.0033	0.0092	0.0072	0.0181	0.0083
66. Bis(2-ethylhexyl)phthalate(4)	0.014	0.023	0.002	0.004	0.031	0.003
67. Butyl benzyl phthalate(4)	0.007	0.011	0.004	0.008	0.017	0.003
68. Di-n-butyl phthalate(4)	0.021	0.025	0.0005	0.015	0.019	0.009
86. Toluene(2)	0.0085	0.0046	0.0042	ND	0.0063	ND
TSS	161.0	159.0	22.0	170.0	142.0	138.0
O&G	65.0	71.0	47.0	39.0	113.0	39.0
pH	6.62	6.64	4.01	6.77	6.82	6.92

*Data recorded as submitted by Reynolds Aluminum Company

(1) Direct Aqueous Injection, Flame Ionization Detector
(2) Headspace Assay - Detection Limit = 0.0005 mg/1
(3) Extraction - EPA Method 611 - Detection Limit = 0.0002 mg/1
(4) EPA Method 606 - with Extraction

SECTION VI

SELECTION OF POLLUTANT PARAMETERS

Section V presented pollutant parameters to be examined for possible regulation along with data from plant sampling visits and subsequent chemical analysis. Priority, nonconventional, and conventional pollutant parameters were selected according to a specified rationale. Pollutant parameters not detected, or detected at not quantifiable concentrations were eliminated from further consideration for regulation. All others which were detected are discussed in this section. The selected priority pollutant parameters are discussed in numerical order, followed by nonconventional pollutants and then conventional pollutant parameters, each in alphabetical order.

Finally, the pollutant parameters selected for consideration for specific regulation and those dropped from further consideration are set forth. The rationale for that selection is also presented. The occurrence and levels of pollutants found are drawn from Table V-11 (page 65), with supplemental information from Tables V-10, V-15, V-17, and V-21 (pages 64, 76, 78 and 80 respectively).

POLLUTANT PARAMETERS

Table VI-1 (page 134) lists all the priority pollutant parameters. For those not followed by an ND or NQ a discussion is presented in this section. The discussion provides information about: where the pollutant comes from - whether it is a naturally occurring element, processed metal, or manufactured compound; general physical properties and the form of the pollutants; toxic effects of the pollutant in humans and other animals; and behavior of the pollutant in POTW at the concentrations that might be expected from industrial discharges. Specific literature relied upon for the following discussion is listed in Section XV. Particular weight has been given to documents generated by the EPA Criteria and Standards Division and Monitoring and Data Support Division.

1,1,1-Trichloroethane (11). 1,1,1-Trichloroethane is one of the two possible trichloroethanes. It is manufactured by hydrochlorinating vinyl chloride to 1,1-dichloroethane which is then chlorinated to the desired product. 1,1,1-Trichloroethane is a liquid at room temperature with a vapor pressure of 96 mm Hg at 20°C and a boiling point of 74°C. Its formula is CCl_3CH_3. It is slightly soluble in water (0.48 g/l) and is very soluble in organic solvents. U.S. annual production is greater than one-third of a million tons.

1,1,1-Trichloroethane is used as an industrial solvent and degreasing agent.

Most human toxicity data for 1,1,1-trichloroethane relates to inhalation and dermal exposure routes. Limited data are available for determining toxicity of ingested 1,1,1-trichloroethane, and those data are all for the compound itself not solutions in water. No data are available regarding its toxicity to fish and aquatic organisms. For the protection of human health from the toxic properties of 1,1,1-trichloroethane ingested through the consumption of water and fish, the ambient water criterion is 18.4 mg/l. The criterion is based on bioassay for possible carcinogenicity.

No detailed study of 1,1,1-trichloroethane behavior in POTW is available; however, it has been demonstrated that none of the organic priority pollutants of this type can be broken down by biological treatment processes as readily as fatty acids, carbohydrates, or proteins.

Biochemical oxidation of many of the organic priority pollutants has been investigated in laboratory scale studies at concentrations higher than commonly expected in municipal wastewater. General observations relating molecular structure to ease of degradation have been developed for all of these pollutants. The conclusion reached by study of the limited data is that biological treatment produces a moderate degree of degradation of 1,1,1-trichloroethane. No evidence is available for drawing conclusions about its possible toxic or inhibitory effect on POTW operation; however, for degradation to occur, a fairly constant input of the compound would be necessary.

Its water solubility would allow 1,1,1-trichloroethane, present in the influent and not biodegradable, to pass through a POTW into the effluent. One factor which has received some attention, but no detailed study, is the volatilization of the lower molecular weight organics from POTW. If 1,1,1-trichloroethane is not biodegraded, it will volatilize during aeration processes in the POTW.

1,1-Dichloroethane (13). 1,1-Dichloroethane, also called ethylidene dichloride and ethylidene chloride is a colorless liquid manufactured by reacting hydrogen chloride with vinyl chloride in 1,1-dichloroethane solution in the presence of a catalyst. However, it is reportedly not manufactured commercially in the U.S. 1,1-dichloroethane boils at 57°C and has a vapor pressure of 182 mm Hg at 20°C. It is slightly soluble in water (5.5 g/l at 20°C) and very soluble in organic solvents.

1,1-Dichloroethane is used as an extractant for heat-sensitive substances and as a solvent for rubber and silicone grease.

1,1-dichloroethane is less toxic than its isomer (1,2-dichloroethane) but its use as an anesthetic has been discontinued because of marked excitation of the heart. It causes central nervous system depression in humans. There are insufficient data to derive water quality criteria for 1,1-dichloroethane.

Data on the behavior of 1,1-dichloroethane in POTW are not available. Many of the organic priority pollutants have been investigated, at least in laboratory scale studies, at concentrations higher than those expected to be contained by most municipal wastewaters. General observations have been developed relating molecular structure to ease of degradation for all of the organic priority pollutants. The conclusion reached by study of the limited data is that biological treatment produces only a moderate removal of 1,1-dichloroethane in POTW by degradation.

The high vapor pressure of 1,1-dichloroethane is expected to result in volatilization of some of the compound from aerobic processes in POTW. Its water solubility will result in some of the 1,1-dichloroethane which enters the POTW leaving in the effluent from the POTW.

1,1,2,2-Tetrachloroethane (15). 1,1,2,2-Tetrachloroethane, also called acetylene tetrachloride and sym-tetrachloroethane ($CHCl_2CHCl_2$), is a heavy, nonflammable liquid with a sweetish odor. It is manufactured by direct chlorination or oxychlorination utilizing ethylene as a feedstock. Its major use is as a feedstock in the manufacture of trichloroethylene, tetrachloroethylene, and 1,1-dichloroethylene. Most often, the 1,1,2,2-tetrachloroethane is not isolated from the reaction mixture when it is prepared, but is immediately converted to the desired end products by thermal cracking. 1,1,2,2-Tetrachloroethane boils at 146.3 C and has a vapor pressure of 4.9 mm Hg at 20°C. It is slightly soluble in water (3.2 g/1000 g water) at 25°C and is miscible with chlorinated solvents.

1,1,2,2-Tetrachloroethane is used as a solvent, metal cleaner, and paint remover but its use is discourgaged because it is highly toxic. It is also used as a weed killer. The reported lethal oral dose for dogs is 0.3 ml/kg body weight. Although cats and rabbits did not show organ damage after 4 weeks of 8 hour daily exposure to 100-160 ppm vapors, injuries to workers have been reported at lower vapor concentrations.

Available data for freshwater aquatic life shows that 1,1,2,2-tetrachloroethane produces acute toxicity effects at 9.32 mg/l. Acute and chronic toxicity would occur at lower concentrations among species that are more sensitive than those tested.

For the maximum protection of human health from the potential carcinogenic effects due to exposure of 1,1,2,2-tetrachloroethane through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero, based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding recommended criteria are 0.0017 mg/l, 0.00017 mg/l, and 0.000017 mg/l, respectively. If the above estimates are made for consumption of aquatic organism only, excluding consumption of water, the levels are 0.107 mg/l, 0.0107 mg/l, and 0.00107 mg/l, respectively.

Although a study of 50 POTW showed 1,1,2,2-tetrachloroethane to be present in a small percentage of influent and effluent samples (less than 10 percent), the concentrations were not great enough to establish percent removal for this compound. It was detected in primary sludge 25 times - at an average concentration of 0.475 mg/l - when it was not detected in the influent to the POTW. This is probably the result of its low solubility in water and high octanol-water partition coefficient (log partition coefficient = 2.56). Although no specific biodegradability test results were found, 1,1,2,2-tetrachloroethane will probably behave as many other chlorinated hydrocarbons do and show no biodegradation. Therefore, it is concluded that little or no removal by biodegradation will occur in a POTW, but it would remain in sludge rather than passing through the POTW.

Bis(2-chloroethyl) ether (18). Bis(2-chloroethyl) ether, also called 1,1'-oxybis(2-chloroethane), 2,2'-dichlorodiethyl ether, bis(beta-chloroethyl) ether, Chlorex, and 1-chloro-2-(beta-chloroethoxy) ethane, ($ClCH_2CH_2OCH_2CH_2Cl$), is a colorless liquid boiling at 178°C. It is made by the action of sulfuric acid on ethylene chlorohydrin. It is slightly soluble in water (10.2 g/l at 25°C) ahd has vapor pressure of 5.3 mm Hg at 20 C.

Bis(2-chloroethyl) ether is used as a soil fumigant, as a solvent in paints, varnishes, and lacquers, and as a solvent for extracting lubricating oil stocks (Chlorex Process).

For the maximum protection of human health from the potential carcinogenic effects due to exposure to bis(2-chloroethyl) ether through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentrations should be zero, based on the nonthreshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10^{-5}, 10^{-6}, 10^{-7}. The corresponding recommended criteria are 0.0003 mg/l, 0.00003 mg/l, and 0.000003 mg/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 0.0136 mg/l, 0.00136 mg/l, and 0.000136 mg/l, respectively.

In three studies of POTW made by EPA, bis(2-chloroethyl) ether was found in one out of 60 samples during a 30-day study at one plant, and in 3 out of 30 samples of primary effluent in a 10-plant study. The concentration found in the 30-day study was 0.748 mg/l; the 3 found in the 10-plant study were 0.004 mg/l or less. The compound was not found in primary or secondary sludges nor in final effluent. A 40-plant study using about 290 samples reported no detected concentrations of bis(2-chloroethyl) ether. These data were considered not sufficient to establish a percent removal or a removal mechanism (i.e., sludge deposition, volatilization, biodegradation) for POTW.

Chloroform (23). Chloroform also called trichloromethane, is a colorless liquid manufactured commercially by chlorination of methane. Careful control of conditions maximizes chloroform production, but other products must be separated. Chloroform boils at 61°C and has a vapor pressure of 200 mm Hg at 25°C. It is slightly soluble in water (8.22 g/l at 20°C) and readily soluble in organic solvents.

Chloroform is used as a solvent and to manufacture refrigerants, pharmaceuticals, plastics, and anesthetics. It is seldom used as an anesthetic.

Toxic effects of chloroform on humans include central nervous system depression, gastrointestinal irritation, liver and kidney damage and possible cardiac sensitization to adrenalin. Carcinogenicity has been demonstrated for chloroform on laboratory animals.

For the maximum protection of human health from the potential carcinogenic effects of exposure to chloroform through ingestion of water and contaminated aquatic organisms, the ambient water concentration is zero based on the nonthreshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime estimated at 10^{-7}, 10^{-6}, and 10^{-5} are 0.000019 mg/l, 0.00019 mg/l, and 0.0019 mg/l, respectively.

No data are available regarding the behavior of chloroform in a POTW. However, the biochemical oxidation of this compound was studied in one laboratory scale study at concentrations higher than those expected to be contained by most municipal wastewaters. After 5, 10, and 20 days no degradation of chloroform was observed. The conclusion reached is that biological treatment produces little or no removal by degradation of chloroform in a POTW.

The high vapor pressure of chloroform is expected to result in volatilization of the compound from aerobic treatment steps in a POTW. Remaining chloroform is expected to pass through into the POTW effluent.

1,1-Dichloroethylene (29). 1,1-Dichloroethylene (1,1-DCE), also called vinylidene chloride, is a clear colorless liquid manufactured by dehydrochlorination of 1,1,2-trichloroethane. 1,1-DCE has the formula CCl_2CH_2. It has a boiling paint of 32°C, and a vapor pressure of 591 mm Hg at 25°C. 1,1-DCE is slightly soluble in water (2.5 mg/l) and is soluble in many organic solvents. U.S. production is in the range of hundreds of thousands of tons annually.

1,1-DCE is used as a chemical intermediate and for copolymer coatings or films. It may enter the wastewater of an industrial facility as the result of decomposition of 1,1,1-trichloroethylene used in degreasing operations, or by migration from vinylidene chloride copolymers exposed to the process water.

Human toxicity of 1,1-DCE has not been demonstrated, although it is a suspected human carcinogen. Mammalian toxicity studies have focused on the liver and kidney damage produced by 1,1-DCE. Various changes occur in those organs in rats and mice ingesting 1,1-DCE.

For the maximum protection of human health from the potential carcinogenic effects of exposure to 1,1-dichloroethylene through ingestion of water and contaminated aquatic organisms, the ambient water concentration is zero. The concentration of 1,1-DCE estimated to result in additional lifetime cancer risks of 10^{-5}, 10^{-6}, and 10^{-7} are estimated to be 0.00033 mg/l, 0.000033 mg/l and 0.0000033 mg/l. If contaminated organisms alone are consumed excluding the consumption of water, the water concentration should be less than 0.019 mg/l to keep the lifetime cancer risk below 10^{-5}.

Under laboratory conditions, dichloroethylenes have been shown to be toxic to fish. Limited acute and chronic toxicity data for aquatic life show that adverse effects occur at concentrations higher than those cited for human health risks. The primary effect of acute toxicity of the dichloroethylenes is depression of the central nervous system. The octanol-water partition coefficient of 1,1-DCE indicates it should not accumulate significantly in animals.

The behavior of 1,1-DCE in POTW has not been studied. However, its very high vapor pressure is expected to result in release of significant percentages of this material to the atmosphere in any treatment involving aeration. Degradation of dichloroethylene in air is reported to occur, with a half-life of 8 weeks.

Biochemical oxidation of many of the organic priority pollutants has been investigated in laboratory-scale studies at concentrations higher than would normally be expected in municipal wastewaters. General observations relating molecular structure to ease of degradation have been developed for all of these pollutants. The conclusion reached by study of the limited data is that biological treatment in POTW produces little or no biochemical oxidation of 1,1-dichloroethylene. No evidence is available for drawing conclusions about the possible toxic or inhibitory effect of 1,1-DCE on POTW operation. Because of water solubility, 1,1-DCE which is not volatilized or degraded is expected to pass through POTW. Very little 1,1-DCE is expected to be found in sludge from POTW.

Methylene Chloride (44). Methylene chloride, also called dichloromethane (CH_2Cl_2), is a colorless liquid manufactured by chlorination of methane or methyl chloride followed by separation from the higher chlorinated methanes formed as coproducts. Methylene chloride boils at 40°C, and has a vapor pressure of 362 mm Hg at 20°C. It is slightly soluble in water (20 g/l at 20°C), and very soluble in organic solvents. U.S. annual production is about 250,000 tons.

Methylene chloride is a common industrial solvent found in insecticides, metal cleaners, paint, and paint and varnish removers.

Methylene chloride is not generally regarded as highly toxic to humans. Most human toxicity data are for exposure by inhalation. Inhaled methylene chloride acts as a central nervous system depressant. There is also evidence that the compound causes heart failure when large amounts are inhaled.

Methylene chloride does produce mutation in tests for this effect. In addition, a bioassay recognized for its extremely high sensitivity to strong and weak carcinogens produced results which were marginally significant. Thus potential carcinogenic effects of methylene chloride are not confirmed or denied, but are under continuous study. Difficulty in conducting and interpreting the test results from the low boiling point (40°C) of methylene chloride which increases the difficulty of maintaining the compound in growth media during incubation at 37°C; and from the difficulty of removing all impurities, some of which might themselves be carcinogenic.

For the protection of human health from the potential carcinogenic effects due to exposure to methylene chloride through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the nonthreshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10^{-5}, 10^{-6} and 10^{-7}. The corresponding recommended criteria are 0.0019 mg/l, 0.00019 mg/l, and 0.000019 mg/l.

The behavior of methylene chloride in a POTW has not been studied in any detail. However, the biochemical oxidation of this conpound was studied on a laboratory scale at concentrations higher than those expected to be contained by most municipal wastewaters. After five days no degradation of methylene chloride was observed. The conclusion reached is that biological treatment produces little or no removal by degradation of methylene choride in a POTW.

The high vapor pressure of methylene chloride is expected to result in volatilization of the compound from aerobic treatment steps in a POTW. It has been reported that methylene chloride inhibits anerobic processes in a POTW. Methylene chloride that is not volatillized in the POTW is expected to pass through into the effluent.

Pentachlorophenol (64). Pentachlorophenol (C_6Cl_5OH) is a white crystalline solid produced commercially by chlorination of phenol or polychlorophenols. U.S. annual production is in excess of 20,000 tons. Pentachlorophenol melts at 190°C and is slightly soluble in water (15 mg/l). Pentachlorophenol is not detected by the 4-amino antipyrene method.

Pentachlorophenol is a bactericide and fungicide and is used for preservation of wood and wood products. It is competitive with creosote in that application. It is also used as a preservative in glues, starches, and photographic papers. It is an effective algicide and herbicide.

Although data are available on the human toxicity effects of pentachlorophenol, interpretation of data is frequently uncertain. Occupational exposure observations must be examined carefully because exposure to pentachlorophenol is frequently accompanied by exposure to other wood preservatives. Additionally, experimental results and occupational exposure observations must be examined carefully to make sure that observed effects are produced by the pentachlorophenol itself and not by the by-products which usually contaminate pentachlorophenol.

Acute and chronic toxic effects of pentachlorophenol in humans are similar; muscle weakness, headache, loss of appetite, abdominal pain, weight loss, and irritation of skin, eyes, and respiratory tract. Available literature indicates that pentachlorophenol does not accumulate in body tissues to any significant extent. Studies on laboratory animals of distribution of the compound in body tissues showed the highest levels of pentachlorophenol in liver, kidney, and intestine, while the lowest levels were in brain, fat, muscle, and bone.

Toxic effects of pentachlorophenol in aquatic organisms are much greater at pH of 6 where this weak acid is predominantly in the undissociated form than at pH of 9 where the ionic form predominates. Similar results were observed in mammals where oral lethal doses of pentachlorophenol were lower when the compound was administered in hydrocarbon solvents(un-ionized form) than when it was administered as the sodium salt (ionized form) in water.

There appear to be no significant teratogenic, mutagenic, or carcinogenic effects of pentachlorophenol.

For the protection of human health from the toxic properties of pentachlorophenol ingested through water and through contaminated aquatic organisms, the ambient water quality criterion is determined to be 1.01 mg/l.

Only limited data are available for reaching conclusions about the behavior of pentachlorophenol in POTW. Pentachlorophenol has been found in the influent to POTW. In a study of one POTW the mean removal was 59 percent over a 7 day period. Trickling filters removed 44 percent of the influent pentachlorophenol, suggesting that biological degradation occurs. The same report compared removal of pentachlorophenol of the same plant and two additional POTW on a later date and obtained values of 4.4, 19.5 and 28.6 percent removal, the last value being for the plant which had 59 percent removal in the original study. Influent concentrations of pentachlorophenol ranged from 0.0014 to 0.0046 mg/l. Other studies, including the general review of data relating molecular structure to biological oxidation, indicate that pentachlorophenol is not removed by biological treatment processes in POTW. Anaerobic digestion processes are inhibited by 0.4 mg/l pentachlorophenol.

The low water solubility and low volatility of pentachlorophenol lead to the expectation that most of the compound will remain in the sludge in a POTW. The effect on plants grown on land treated with pentachlorophenol - containing sludge is unpredictable. Laboratory studies show that this compound affects crop germination at 5.4 mg/l. However, photodecomposition of pentachlorophenol occurs in sunlight. The effects of the various breadkown products which may remain in the soil was not found in the literature.

Phthalate Esters (66-71). Phthalic acid, or 1,2-benzenedicarboxylic acid, is one of three isomeric benzenedicarboxylic acids produced by the chemical industry. The other two isomeric forms are called isophthalic and terephthalic acids. The formula for all three acids is $C_6H_4(COOH)_2$. Some esters of phthalic acid are designated as priority pollutants. They will be discussed as a group here, and specific properties of individual phthalate esters will be discussed afterwards.

Over one billion pounds of phthalic acid esters are manufactured in the U.S. annually. They are used as plasticizers - primarily in the production of polyvinyl chloride (PVC) resins. The most widely used phthalate plasticizer is bis (2-ethylhexyl) phthalate (66) which accounts for nearly one third of the phthalate esters produced. This particular ester is commonly referred to as dioctyl phthalate (DOP) and should not be confused with one of the less used esters, di-n-octyl phthalate (69), which is also used as a plasticizer. In addition to these two isomeric dioctyl phthalates, four other esters, also used primarily as plasticizers, are designated as priority pollutants. They are: butyl benzyl phthalate (67); di-n-butyl phthalate (68); diethyl phthalate (70); and dimethyl phthalate (71).

Industrially, phthalate esters are prepared from phthalic anhydride and the specific alcohol to form the ester. Some evidence is available suggesting that phthalic acid esters also may be synthesized by certain plant and animal tissues. The extent to which this occurs in nature is not known.

Phthalate esters used as plasticizers can be present in concentrations of up to 60 percent of the total weight of the PVC plastic. The plasticizer is not linked by primary chemical bonds to the PVC resin. Rather, it is locked into the structure of intermeshing polymer molecules and held by van der Waals forces. The result is that the plasticizer is easily extracted. Plasticizers are responsible for the odor associated with new plastic toys or flexible sheet that has been contained in a sealed package.

Although the phthalate esters are not soluble or are only very slightly soluble in water, they do migrate into aqueous solutions placed in contact with the plastic. Thus industrial facilities with tank linings, wire and cable coverings, tubing, and sheet flooring of PVC are expected to discharge some phthalate esters in their raw waste. In addition to their use as plasticizers, phthalate esters are used in lubricating oils and pesticide carriers. These also can contribute to industrial discharge of phthalate esters.

The accumulated data on acute toxicity in animals suggest that phthalate esters have a rather low order of toxicity. Human toxicity data are limited. It is thought that the toxic effects of the esters are most likely due to one of the metabolic products, in particular the monoester. Oral acute toxicity in animals is greater for the lower molecular weight esters than for the higher molecular weight esters.

Orally administered phthalate esters generally produced enlarging of liver and kidney, and atrophy of testes in laboratory animals. Specific esters produced enlargement of heart and brain, spleenitis, and degeneration of central nervous system tissue.

Subacute doses administered orally to laboratory animals produced some decrease in growth and degeneration of the testes. Chronic studies in animals showed similar effects to those found in acute and subacute studies, but to a much lower degree. The same organs were enlarged, but pathological changes were not usually detected.

A recent study of several phthalic esters produced suggestive but not conclusive evidence that dimethyl and diethyl phthalates have a cancer liability. Only four of the six priority pollutant esters were included in the study. Phthalate esters do bioconcentrate in fish. The factors, weighted for relative consumption of various aquatic and marine food groups, are used to calculate ambient water quality criteria for four phthalate esters. The values are included in the discussion of the specific esters.

Studies of toxicity of phthalate esters in freshwater and salt water organisms are scarce. A chronic toxicity test with bis(2-ethylhexyl) phthalate showed that significant reproductive impairment occurred at 0.003 mg/l in the freshwater crustacean, Daphnia magna. In acute toxicity studies, saltwater fish and organisms showed sensitivity differences of up to eight-fold to butyl benzyl, diethyl, and dimethyl phthalates. This suggests that each ester must be evaluated individually for toxic effects.

The behavior of phthalate esters in POTW has not been studied. However, the biochemical oxidation of many of the organic priority pollutants has been investigated in laboratory-scale studies at concentrations higher than would normally be expected in municipal wastewater. Three of the phthalate esters were studied. Bis(2-ethylhexyl) phthalate was found to be degraded slightly or not at all and its removal by biological treatment in a POTW is expected to be slight or zero. Di-n-butyl phthalate and diethyl phthalate were degraded to a moderate degree and their removal by biological treatment in a POTW is expected to occur to a moderate degree. Using these data and other observations relating molecular structure to ease of biochemical degradation of other organic pollutants, the conclusion was reached that butyl benzyl phthalate and dimethyl phthalate would be removed in a POTW to a moderate degree by biological treatment. On the same basis, it was concluded that di-n-octyl phthalate would be removed to a slight degree or not at all.

No information was found on possible interference with POTW operation or the possible effects on sludge by the phthalate esters. The water insoluble phthalate esters - butyl benzyl and di-n-octyl phthalate - would tend to remain in sludge, whereas the other four priority pollutant phthalate esters with water solubilities ranging from 50 mg/l to 4.5 mg/l would probably pass through into the POTW effluent.

Bis (2-ethylhexyl) phthalate (66). Little information is available about the physical properties of bis(2-ethylhexyl) phthalate. It is a liquid boiling at 387°C at 5mm Hg and is insoluble in water. Its formula is $C_6H_4(COOC_8H_{17})_2$. This priority pollutant constitutes about one third of the phthalate ester production in the U.S. It is commonly referred to as dioctyl phthalate, or DOP, in the plastics industry where it is the most extensively used compound for the plasticization of polyvinyl chloride (PVC). Bis(2-ethylhexyl) phthalate has been approved by the FDA for use in plastics in contact with food. Therefore, it may be found in wastewaters coming in contact with discarded plastic food wrappers as well as the PVC films and shapes normally found in industrial plants. This priority pollutant is also a commonly used organic diffusion pump oil where its low vapor pressure is an advantage.

For the protection of human health from the toxic properties of bis(2-ethylhexyl) phthalate ingested through water and through contaminated aquatic organisms, the ambient water quality criterion is determined to be 15 mg/l.

Although the behavior of bis(2-ethylhexyl) phthalate in POTW has not been studied, biochemical oxidation of this priority pollutant has been studied on a laboratory scale at concentrations higher than would normally be expected in municipal wastewater. In fresh water with a non-acclimated seed culture, no biochemical oxidation was observed after 5, 10, and 20 days; with an acclimated seed culture, however, biological oxidation of 13, 0, 6, and 23 percent of theoretical occurred after 5, 10, 15 and 20 days, respectively. Bis(2-ethylhexyl) phthalate concentrations were 3 to 10 mg/l. Little or no removal of bis(2-ethylhexyl) phthalate by biological treatment in POTW is expected.

Butyl benzyl phthalate (67). No information was found on the physical properties of this compound.

Butyl benzyl phthalate is used as a plasticizer for PVC. Two special applications differentiate it from other phthalate esters. It is approved by the U.S. FDA for food contact in wrappers and containers; and it is the industry standard for plasticization of vinyl flooring because it provides stain resistance.

No ambient water quality criterion is proposed for butyl benzyl phthalate.

Butyl benzyl phthalate removal in POTW by biological treatment in a POTW is expected to occur to a moderate degree.

Di-n-butyl phthalate (68). Di-n-butyl phthalate (DBP) is a colorless, oily liquid, boiling at 340°C. Its water solubility at room temperature is reported to be 0.4 g/l and 4.5g/l in two different chemistry handbooks. The formula for DBP, $C_6H_4(COOC_4H_9)_2$ is the same as for its isomer, di-isobutyl phthalate. DBP production is one to two percent of total U.S. phthalate ester production.

DBP is used to a limited extent as a plasticizer for polyvinyl chloride (PVC). It is not approved for contact with food. It is used in liquid lipsticks and as a diluent for polysulfide dental impression materials. DBP is used as a plasticizer for nitrocellulose in making gun powder, and as a fuel in solid propellants for rockets. Further uses are insecticides, safety glass manufacture, textile lubricating agents, printing inks, adhesives, paper coatings and resin solvents.

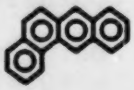
For protection of human health from the toxic properties of dibutyl phthalate ingested through water and through contaminated aquatic organisms, the ambient water quality criterion is determined to be 34 mg/l.

Although the behavior of di-n-butyl phthalate in POTW has not been studied, biochemical oxidation of this priority pollutant has been studied on a laboratory scale at concentrations higher than would normally be expected in municipal wastewater. Biochemical oxidation of 35, 43, and 45 percent of theoretical oxidation was obtained after 5, 10, and 20 days, respectively, using sewage microorganisms as an unacclimated seed culture.

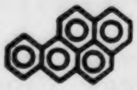
Biological treatment in POTW is expected to remove di-n-butyl phthalate to a moderate degree.

Polynuclear Aromatic Hydrocarbons (72-84). The polynuclear aromatic hydrocarbons (PAH) selected as priority pollutants are a group of 13 compounds consisting of substituted and unsubstituted polycyclic aromatic rings. The general class of PAH includes heterocyclics, but none of those were selected as priority pollutants. PAH are formed as the result of incomplete combustion when organic compounds are burned with insufficient oxygen. PAH are found in coke oven emissions, vehicular emissions, and volatile products of oil and gas burning. The compounds chosen as priority pollutants are listed with their structural formula and melting point (m.p.). All are insoluble in water.

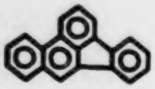
72 Benzo(a)anthracene (1,2-benzanthracene)
m.p. 162°C



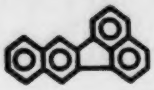
73 Benzo(a)pyrene (3,4-benzopyrene)
m/p. 176°C



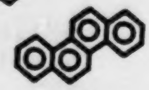
74 3,4-Benzofluoranthene
m.p. 168°C



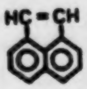
75 Benzo(k)fluoranthene (11, 12-benzofluoranthene)
m.p. 217°C



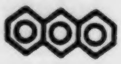
76 Chrysene (1,2-benzophenanthrene)
m.p. 255°C



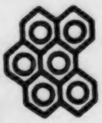
77 Acenaphthylene HC-CH
m.p. 92°C



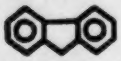
78 Anthracene
m.p. 216°C



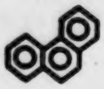
79 Benzo(ghi)perylene (1,12-benzoperylene)
m.p. not reported



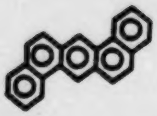
80 Fluorene (alpha-diphenylenemethane)
m.p. 116°C



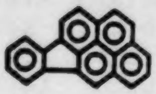
81 Phenanthrene
m.p. 101°C



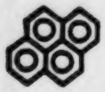
82 Dibenzo(a,h)anthracene (1,2,5,6-dibenzanthracene)
m.p. 269°C



83 Indeno(1,2,3-cd)pyrene (2,3-o-phenylene pyrene)
m.p. not available



84 Pyrene
m.p. 156°C



Some of these priority pollutants have commercial or industrial uses. Benzo(a)anthracene, benzo(a)pyrene, chrysene, anthracene, dibenzo(a,h) anthracene, and pyrene are all used as antioxidants. Chrysene, acenapthylene, anthracene, fluorene, phenanthrene, and pyrene are all used for synthesis of dyestuffs or other organic chemicals. 3,4-Benzofluoranthrene, benzo(k)fluoranthene, benzo(ghi)perylene, and indeno (1,2,3-cd) pyrene have no known industrial uses, according to the results of a recent literature search.

Several of the PAH priority pollutants are found in smoked meats, in smoke flavoring mixtures, in vegetable oils, and in coffee. They are found in soils and sediments in river beds. Consequently, they are also found in many drinking water supplies. The wide distribution of these pollutants in complex mixtures with the many other PAHs which have not been designated as priority pollutants results in exposures by humans that cannot be associated with specific individual compounds.

The screening and verification analysis procedures used for the organic priority pollutants are based on gas chromatography (GC). Three pairs of the PAH have identical elution times on the column specified in the protocol, which means that the parameters of the pair are not differentiated. For these three pairs [anthracene (78) - phenanthrene (81); 3,4-benzofluoranthene (74) - benzo(k)fluoranthene (75); and benzo(a)anthracene (72) - chrysene (76)] results are obtained and reported as "either-or." Either both are present in the combined concentration reported, or one is present in the concentration reported. When detections below reportable limits are recorded no further analysis is required. For samples where the concentrations of coeluting pairs have a significant value, additional analyses are conducted, using different procedures that resolve the particular pair.

There are no studies to document the possible carcinogenic risks to humans by direct ingestion. Air pollution studies indicate an excess of lung cancer mortality among workers exposed to large amounts of PAH containing materials such as coal gas, tars, and coke-oven emissions. However, no definite proof exists that the PAH present in these materials are responsible for the cancers observed.

Animal studies have demonstrated the toxicity of PAH by oral and dermal administration. The carcinogenicity of PAH has been traced to formation of PAH metabolites which in turn lead to tumor formation. Because the levels of PAH which induce cancer are very low, little work has been done on other health hazards resulting from exposure. It has been established in animal studies that tissue damage and systemic toxicity can result from exposure to noncarcinogenic PAH compounds.

Because there were no studies available regarding chronic oral exposures to PAH mixtures, proposed water quality criteria were derived using data on exposure to a single compound. Two studies were selected, one involving benzo(a)pyrene ingestion and one involving dibenzo(a,h)anthracene ingestion. Both are known animal carcinogens.

For the maximum protection of human health from the potential carcinogenic effects of exposure to polynuclear aromatic hydrocarbons (PAH) through ingestion of water and contaminated aquatic organisms, the ambient water concentration is zero. Concentrations of PAH estimated to result in additional lifetime cancer risks of 10^{-5}, 10^{-6}, or 10^{-7} are 0.000028 mg/l, 0.0000028 mg/l, and 0.00000028 mg/l, respectively.

No standard toxicity tests have been reported for freshwater or saltwater organisms exposed to any of the 13 PAH discussed here.

The behavior of PAH in POTW has received only a limited amount of study. Reports have indicated that up to 90 percent of PAH entering a POTW will be retained in the sludge generated by conventional sewage treatment processes. Some of the PAH can inhibit bacterial growth when they are present at concentrations as low as 0.018 mg/l. Biological treatment in activated sludge units has been shown to reduce the concentration of phenanthrene and anthracene to some extent. However, a study of biochemical oxidation of fluorene on a laboratory scale showed no degradation after 5, 10, and 20 days. On the basis of that study and studies of other organic priority pollutants, some general observations were made relating molecular structure to ease of degradation. Those observations lead to the conclusion that the 13 PAH selected to represent that group as priority pollutants will be removed only slightly or not at all by biological treatment methods in POTW. Based on their water insolubility and tendency to attach to sediment particles very little pass through of PAH to POTW effluent is expected.

In an Agency study, Fate of Priority Pollutants in Publicly Owned Treatment Works, the pollutant concentrations in the influent, effluent and (EPA-440/1-80-301, October 1980) sludge of 20 POTW were measured. The results show that indeed the PAH are concentrated in the sludges and that little or no PAH are discharged in the effluent of POTW. The differences in average concentrations from influent to effluent range from 50 to 100 percent removal with all but one PAH above 80 percent removal. The data indicate that all or nearly all of the PAH's are concentrated in the sludge.

No data are available at this time to support any conclusions about contamination of land by PAH on which sewage sludge containing PAH is spread.

Tetrachloroethylene (85). Tetrachloroethylene (CCl_2CCL_2), also called perchloroethylene and PCE, is a colorless nonflammable liquid produced mainly by two methods - chlorination and pyrolysis of ethane and propane, and oxychlorination of dichloroethane. U.S. annual production exceeds 300,000 tons. PCE boils at 121°C and has a vapor pressure of 19 mm Hg at 20°C. It is insoluble in water but soluble in organic solvents.

Approximately two-thirds of PCE is used for dry cleaning. Textile processing and metal degreasing, in equal amounts consume about one-quarter of the U.S. production.

The principal toxic effect of PCE on humans is central nervous system depression when the compound is inhaled. Headache, fatigue, sleepiness, dizziness and sensations of intoxication are reported. Severity of effects increases with vapor concentration. High integrated exposure (concentration times duration) produces kidney and liver damage. Very limited data on PCE ingested by laboratory animals indicate liver damage occurs when PCE is administered by that route. PCE tends to distribute to fat in mammalian bodies.

One report found in the literature suggests, but does not conclude, that PCE is teratogenic. PCE has been demonstrated to be a liver carcinogen in B6C3-F1 mice.

For the maximum protection of human health from the potential carcinogenic effects of exposure to tetrachloroethylene through ingestion of water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding recommended criteria are 0.008 mg/l, 0.0008 mg/l and 0.00008 mg/l.

No data were found regarding the behavior of PCE in POTW. Many of the organic priority pollutants have been investigated, at least in laboratory scale studies, at concentrations higher than those expected to be contained by most municipal wastewaters. General observations have been developed relating molecular structure to ease of degradation for all of the organic priority pollutants. The conclusions reached by the study of the limited data is that biological treatment produces a moderate removal of PCE in POTW by degradation. No information was found to indicate that PCE accumulates in the sludge, but some PCE is expected to be adsorbed onto settling particles. Some PCE is expected to be volatilized in aerobic treatment processes and little, if any, is expected to pass through into the effluent from the POTW.

Toluene(86). Toluene is a clear, colorless liquid with a benzene-like odor. It is a naturally occuring compound derived primarily from petroleum or petrochemical processes. Some toluene is obtained from the manufacture of metallurgical coke. Toluene is also referred to as toluol, methylbenzene, methacide, and phenylmethane. It is an aromatic hydrocarbon with the formula $C_6H_5CH_3$. It boils at 111°C and has a vapor pressure of 30 mm Hg at room temperature. The water solubility of toluene is 535 mg/l, and it is miscible with a variety of organic solvents. Annual production of toluene in the U.S. is greater than 2 million metric tons. Approximately two-thirds of the toluene is converted to benzene; the remaining 30 percent is divided approximately equally into chemical manufacture and use as a paint solvent and aviation gasoline additive. An estimated 5,000 metric tons is discharged to the environment annually as a constituent in wastewater.

Most data on the effects of toluene in human and other mammals have been based on inhalation exposure or dermal contact studies. There appear to be no reports of oral administration of toluene to human subjects. A long term toxicity study on female rats revealed no adverse effects on growth, mortality, appearance and behavior, organ to body weight ratios, blood-urea nitrogen levels, bone marrow counts, peripheral blood counts, or morphology of major organs. The effects of inhaled toluene on the central nervous system, both at high and low concentrations, have been studied in humans and animals. However, ingested toluene is expected to be handled differently by the body because it is absorbed more slowly and must first pass through the liver before reaching the nervous system. Toluene is extensively and rapidly metabolized in the liver. One of the principal metabolic products of toluene is benzoic acid, which itself seems to have little potential to produce tissue injury.

Toluene does not appear to be teratogenic in laboratory animals or man. Nor is there any conclusive evidence that toluene is mutagenic. Toluene has not been demonstrated to be positive in any in vitro mutagenicity or carcinogenicity bioassay system, nor to be carcinogenic in animals or man.

Toluene has been found in fish caught in harbor waters in the vicinity of petroleum and petrochemical plants. Bioconcentration studies have not been conducted, but bioconcentration factors have been calculated on the basis of the octanol-water partition coefficient.

For the protection of human health from the toxic properties of toluene ingested through water and through contaminated aquatic organisms, the ambient water criterion is determined to be 14.3 mg/l. If contaminated aquatic organisms alone are consumed excluding the consumption of water, the ambient water criterion is 424 mg/l. Available data show that the adverse effects on aquatic life occur at concentrations as low as 5 mg/l.

Acute toxicity tests have been conducted with toluene and a variety of freshwater fish and Daphnia magna. The latter appears to be significantly more resistant than fish. No test results have been reported for the chronic effects of toluene on freshwater fish or invertebrate species.

No detailed study of toluene behavior in POTW is available. However, the biochemical oxidation of many of the priority pollutants has been investigated in laboratory scale studies at concentrations greater than those expected to be contained by most municipal wastewaters. At toluene concentrations ranging from 3 to 250 mg/l biochemical oxidation proceeded to fifty percent of theoretical oxidation or greater. The time period varied from a few hours to 20 days, depending on whether or not the seed culture was acclimated. Phenol adapted acclimated seed cultures gave the most rapid and extensive biochemical oxidation. The conclusion reached by study of the limited data is that biological treatment produces moderate removal of toluene in POTW. The volatility and relatively low water solubility of toluene lead to the expectation that aeration processes will remove significant quantities of toluene from the POTW. The EPA studied toluene removal in seven POTW facilities. The removals ranged from 40 to 100 percent. Sludge concentrations of toluene ranged from 54 x 10^{-3} to 1.85 mg/l.

Arsenic (115). Arsenic (chemical symbol As), is classified as a nonmetal or metalloid. Elemental arsenic normally exists in the alpha-crystalline metallic form which is steel gray and brittle, and in the beta form which is dark gray and amorphous. Arsenic sublimes at 615°C. Arsenic is widely distributed throughout the world in a large number of minerals. The most important commercial source of arsenic is as a by-product from treatment of copper, lead, cobalt, and gold ores. Arsenic is usually marketed as the trioxide (As_2O_3). Annual U.S. production of the trioxide approaches 40,000 tons.

The principal use of arsenic is in agricultural chemicals (herbicides) for controlling weeds in cotton fields. Arsenicals have various applications in medicinal and veterinary use, as wood preservatives, and in semiconductors.

The effects of arsenic in humans were known by the ancient Greeks and Romans. The principal toxic effects are gastrointestinal disturbances. Breakdown of red blood cells occurs. Symptoms of acute poisoning include vomiting, diarrhea, abdominal pain, lassitude, dizziness, and headache. Longer exposure produced dry, falling hair, brittle, loose nails, eczema, and exfoliation. Arsenicals also exhibit teratogenic and mutagenic effects in humans. Oral administration of arsenic compounds has been associated clinically with skin cancer for nearly one hundred years. Since 1888 numerous studies have linked occupational exposure and therapeutic administration of arsenic compounds to increased incidence of respiratory and skin cancer.

For the maximum protection of human health from the potential carcinogenic effects of exposure to arsenic through ingestion of water and contaminated aquatic organisms, the ambient water concentration is zero based on the nonthreshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime estimated at 10^{-7}, 10^{-6}, and 10^{-5} are 0.00000022 mg/l, 0.0000022 mg/l, and 0.000022 mg/l, respectively. If contaminated aquatic organisms alone are consumed, excluding the consumption of water, the water concentration should be less than 1.75×10^{-4} to keep the increased lifetime cancer risk below 10^{-5}. Available data show that adverse effects on aquatic life occur at concentrations higher than those cited for human health risks.

A few studies have been made regarding the behavior of arsenic in a POTW. One EPA survey of nine POTW facilities reported influent concentrations ranging from 0.0005 to 0.693 mg/l; effluents from three POTW having biological treatment contained 0.0004 to 0.01 mg/l; two POTW facilities showed arsenic removal efficiencies of 50 and 71 percent in biological treatment. Inhibition of treatment processes by sodium arsenate is reported to occur at 0.1 mg/l in activated sludge, and 1.6 mg/l in anaerobic digestion processes. In another study based on data from 60 POTW facilities, arsenic in sludge ranged from 1.6 to 65.5 mg/kg and the median value was 7.8 mg/kg. Arsenic in sludge spread on cropland may be taken up by plants grown on that land. Edible plants can take up arsenic, but normally their growth is inhibited before the plants are ready for harvest.

Cadmium (118). Cadmium is a relatively rare metallic element that is seldom found in sufficient quantities in a pure state to warrent mining or extraction from the earth's surface. It is found in trace amounts of about 1 ppm throughout the earth's crust. Cadmium is, however, a valuable by-product of zinc production.

Cadmium is used primarily as an electroplated metal, and is found as an impurity in the secondary refining of zinc, lead, and copper.

Cadmium is an extremely dangerous cumulative toxicant, causing progressive chronic poisoning in mammals, fish, and probably other organisms. The metal is not excreted.

Toxic effects of cadmium on man have been reported from throughout the world. Cadmium may be a factor in the development of such human pathological conditions as kidney disease, testicular tumors, hypertension, arteriosclerosis, growth inhibition, chronic diseases of old age, and cancer. Cadmium is normally ingested by humans through food and water as well as by breathing air contaminated by cadmium dust. Cadmium is cumulative in the liver, kidney, pancreas, and thyroid of humans and other animals. A severe bone and kidney syndrome known as itai-itai disease has been documented in Japan as caused by cadmium ingestion via drinking water and contaminated irrigation water. Ingestion of as little as 0.6 mg/day has produced the disease. Cadmium acts synergistically with other metals. Copper and zinc substantially increase its toxicity.

Cadmium is concentrated by marine organisms, particularly molluscs, which accumulate cadmium in calcareous tissues and in the viscera. A concentration factor of 1000 for cadmium in fish muscle has been reported, as have concentration factors of 3000 in marine plants and up to 29,600 in certain marine animals. The eggs and larvae of fish are apparently more sensitive than adult fish to poisoning by cadmium, and crustaceans appear to be more sensitive than fish eggs and larvae.

For the protection of human health from the toxic properties of cadmium ingested through water and through contaminated aquatic organisms, the ambient water criterion is determined to be 0.010 mg/l.

Cadmium is not destroyed when it is introduced into a POTW, and will either pass through to the POTW effluent or be incorporated into the POTW sludge. In addition, it can interfere with the POTW treatment process.

In a study of 189 POTW, 75 percent of the primary plants, 57 percent of the trickling filter plants, 66 percent of the activated sludge plants and 62 percent of the biological plants allowed over 90 percent of the influent cadmium to pass through to the POTW effluent. Only 2 of the 189 POTW allowed less than 20 percent pass-through, and none less than 10 percent pass-through. POTW effluent concentrations ranged from 0.001 to 1.97 mg/l (mean 0.028 mg/l, standard deviation 0.167 mg/l).

Cadmium not passed through the POTW will be retained in the sludge, where it is likely to build up in concentration. Cadmium contamination of sewage sludge limits its use on land since it increases the level of cadmium in the soil. Data show that cadmium can be incorporated into crops, including vegetables and grains, from contaminated soils. Since the crops themselves show no adverse effects from soils with levels up to 100 mg/kg cadmium, these contaminated crops could have a significant impact on human health. Two Federal agencies have already recognized the potential adverse human health effects posed by the use of sludge on cropland. The FDA recommends that sludge containing over 30 mg/kg of cadmium should not be used on agricultural land. Sewage sludge contains 3 to 300 mg/kg (dry basis) of cadmium mean = 10 mg/kg; median = 16 mg/kg. The USDA also recommends placing limits on the total cadmium from sludge that may be applied to land.

Chromium (119). Chromium is an elemental metal usually found as a chromite ($FeO \bullet Cr_2O_3$). The metal is normally produced by reducing the oxide with aluminum. A significant proportion of the chromium used is in the form of compounds such as sodium dichromate (Na_2CrO_4), and chromic acid (CrO_3) - both are hexavalent chromium compounds.

Chromium and its compounds are used in the canmaking subcategory of the coil coating industry. As the metal, it is found as an alloying component of many steels.

The two chromium forms most frequently found in industry wastewaters are hexavalent and trivalent chromium. Hexavalent chromium is the form used for metal treatments. Some of it is reduced to trivalent chromium as part of the process reaction. The raw wastewater containing both valence states is usually treated first to reduce remaining hexavalent to trivalent chromium, and second to precipitate the trivalent form as the hydroxide. The hexavalent form is not removed by lime treatment.

Chromium, in its various valence states, is hazardous to man. It can produce lung tumors when inhaled, and induces skin sensitizations. Large doses of chromates have corrosive effects on the intestinal tract and can cause inflammation of the kidneys. Hexavalent chromium is a known human carcinogen.

The toxicity of chromium salts to fish and other aquatic life varies widely with the species, temperature, pH, valence of the chromium, and synergistic or antagonistic effects, especially the effect of water hardness. Studies have shown that trivalent chromium is more toxic to fish of some types than is hexavalent chromium. Hexavalent chromium retards growth of one fish species at 0.0002 mg/l. Fish food organisms and other lower forms of aquatic life are extremely sensitive to chromium. Therefore, both hexavalent and trivalent chromium must be considered harmful to particular fish or organisms.

For the protection of human health from the toxic properties of chromium (except hexavalent chromium) ingested through water and contaminated aquatic organisms, the recommended water qualtiy criterion is 170 mg/l.

For the protection of human health from the toxic effects of exposure to hexavalent chromium through ingestion of water and contaminated aquatic organisms, the ambient water concentration is zero.

Chromium is not destroyed when treated by POTW (although the oxidation state may change), and will either pass through to the POTW effluent or be incorporated into the POTW sludge. Both oxidation states can inhibit POTW treatment and can also limit the usefuleness of municipal sludge.

EPA has observed influent concentrations of chromium to POTW facilities to range from 0.005 to 14.0 mg/l, with a median concentration of 0.1 mg/l. The efficiencies for removal of chromium by the activated sludge process can vary greatly, depending on chromium concentration in the influent, and other operating conditions at the POTW. Chelation of chromium by organic matter and dissolution due to the presence of carbonates can cause deviations from the predicted behavior in treatment systems.

The systematic presence of chromium compounds will halt nitrification in a POTW for short periods, and most of the chromium will be retained in the sludge solids. Hexavalent chromium has been reported to severely affect the nitrification process, but trivalent chromium has little or no toxicity to activated sludge, except at high concentrations. The presence of iron, copper, and low pH will increase the toxicity of chromium in a POTW by releasing the chromium into solution to be ingested by microorganisms in the POTW.

The amount of chromium which passes through to the POTW effluent depends on the type of treatment processes used by the POTW. In a study of 240 POTW, 56 percent of the primary plants allowed more than 80 percent pass through to POTW effluent. More advanced treatment results in less pass-through. POTW effluent concentrations ranged from 0.003 to 3.2 mg/l total chromium (mean = 0.197, standard deviation = 0.48), and from 0.002 to 0.1 mg/l hexavalent chromium (mean = 0.017, standard deviation = 0.020).

Chromium not passed through the POTW will be retained in the sludge, where it is likely to build up in concentration. Sludge concentrations of total chromium of over 20,000 mg/kg (dry basis) have been observed. Disposal of sludges containing very high concentrations of trivalent chromium can potentially cause problems in uncontrollable landfills. Incineration, or similar destructive oxidation processes can produce hexavalent chromium from lower valance states. Hexavalent chromium is potentially more toxic than trivalent chromium. In cases where high rates of chrome sludge application on land are used, distinct growth inhibition and plant tissue uptake have been noted.

Pretreatment of discharges substantially reduces the concentration of chromium in sludge. In Buffalo, New York, pretreatment of electroplating waste resulted in a decrease in chromium concentrations in POTW sludge from 2,510 to 1,040 mg/kg. A similar reduction occurred in a Grand Rapids, Michigan, POTW where the chromium concentration in sludge decreased from 11,000 to 2,700 mg/kg when pretreatment was required.

Copper (120). Copper is a metallic element that sometimes is found free, as the native metal, and is also found in minerals such as cuprite (Cu_2O), malechite [$CuCO_3 \bullet Cu(OH)_2$], azurite [$2CuCO_3 \bullet Cu(OH)_2$], chalcopyrite ($CuFeS_2$), and bornite (Cu_5FeS_4). Copper is obtained from these ores by smelting, leaching, and electrolysis. It is used in the plating, electrical, plumbing, and heating equipment industries, as well as in insecticides and fungicides. In the canmaking subcategory of the coil coating industry copper can be attributed to various contaminant sources.

Traces of copper are found in all forms of plant and animal life, and the metal is an essential trace element for nutrition. Copper is not considered to be a cumulative systemic poison for humans because it is readily excreted by the body, but it can cause symptoms of gastroenteritis, with nausea and intestinal irritations, at relatively low dosages. The limiting factor in domestic water supplies is taste. To prevent this adverse organoleptic effect of copper in water, a criterion of 1 mg/l has been established.

The toxicity of copper to aquatic organisms varies significantly, not only with the species, but also with the physical and chemical characteristics of the water, including temperature, hardness, turbidity, and carbon dioxide content. In hard water, the toxicity of copper salts may be reduced by the precipitation of copper carbonate or other insoluble compounds. The sulfates of copper and zinc, and of copper and calcium are synergistic in their toxic effect on fish.

Relatively high concentrations of copper may be tolerated by adult fish for short periods of time; the critical effect of copper appears to be its higher toxicity to young or juvenile fish. Concentrations of 0.02 to 0.031 mg/l have proved fatal to some common fish species. In general the salmonoids are very sensitive and the sunfishes are less sensitive to copper.

The recommended criterion to protect saltwater aquatic life is 0.004 mg/l as a 24-hour average, and 0.023 mg/l maximum concentration.

Copper salts cause undesirable color reactions in the food industry and cause pitting when deposited on some other metals such as aluminum and galvanized steel.

Irrigation water containing more than minute quantities of copper can be detrimental to certain crops. Copper appears in all soils, and its concentration ranges from 10 to 80 ppm. In soils, copper occurs in association with hydrous oxides of manganese and iron, and also as soluble and insoluble complexes with organic matter. Copper is essential to the life of plants, and the normal range of concentration in plant tissue is from 5 to 20 ppm. Copper concentrations in plants normally do not build up to high levels when toxicity occurs. For example, the concentrations of copper in snapbean leaves and pods were less than 50 and 20 mg/kg, respectively, under conditions of severe copper toxicity. Even under conditions of copper toxicity, most of the excess copper accumulates in the roots; very little is moved to the aerial part of the plant.

Copper is not destroyed when treated by a POTW, and will either pass through to the POTW effluent or be retained in the POTW sludge. It can interfere with the POTW treatment processes and can limit the usefulness of municipal sludge.

The influent concentration of copper to POTW facilities has been observed by the EPA to range from 0.01 to 1.97 mg/l, with a median concentration of 0.12 mg/l. The copper that is removed from the influent stream of a POTW is adsorbed on the sludge or appears in the sludge as the hydroxide of the metal. Bench scale pilot studies have shown that from about 25 percent to 75 percent of the copper passing through the activated sludge process remains in solution in the final effluent. Four-hour slug dosages of copper sulfate in concentrations exceeding 50 mg/l were reported to have severe effects on the removal efficiency of an unacclimated system, with the system returning to normal in about 100 hours. Slug dosages of copper in the form of copper cyanide were observed to have much more severe effects on the activated sludge system, but the total system returned to normal in 24 hours.

In a recent study of 268 POTW, the median pass-through was over 80 percent for primary plants and 40 to 50 percent for trickling filter, activated sludge, and biological treatment plants. POTW effluent concentrations of copper ranged from 0.003 to 1.8 mg/l (mean 0.126, standard deviation 0.242).

Copper which does not pass through the POTW will be retained in the sludge where it will build up in concentration. The presence of excessive levels of copper in sludge may limit its use on cropland. Sewage sludge contains up to 16,000 mg/kg of copper, with 730 mg/kg as the mean value. These concentrations are significantly greater than those normally found in soil, which usually range from 18 to 80 mg/kg. Experimental data indicate that when dried sludge is spread over tillable land, the copper tends to remain in place down to the depth of tillage, except for copper which is taken up by plants grown in the soil. Recent investigation has shown that the extractable copper content of sludge-treated soil decreased with time, which suggests a reversion of copper to less soluble forms was occurring.

Cyanide (121). Cyanides are among the most toxic of pollutants commonly observed in industrial wastewaters. Introduction of cyanide into industrial processes is usually by dissolution of potassium cyanide (KCN) or sodium cyanide (NaCN) in process waters; however, the hydrogen cyanide (HCN) formed when the above salts are dissolved in water is probably the most acutely lethal compound.

The relationship of pH to hydrogen cyanide formation is very important. As pH decreases below 7, more than 99 percent of the cyanide is present as HCN and less than 1 percent as cyanide ions. Thus, at neutral pH, that of most living organisms, the more toxic form of cyanide prevails.

Cyanide ions combine with numerous heavy metal ions to form complexes. The complexes are in equilibrium with HCN. Thus, the stability of the metal-cyanide complex and the pH determine the concentration of HCN. Stability of the metal-cyanide anion complexes is extremely variable. Those formed with zinc, copper, and cadmium are not stable - they rapidly dissociate, with production of HCN, in near neutral or acid waters. Some of the complexes are extremely stable. Cobaltocyanide is very resistant to acid distillation in the laboratory. Iron cyanide complexes are also stable, but undergo photodecomposition to give HCN upon exposure to sunlight. Synergistic effects have been demonstrated for the metal cyanide complexes making zinc, copper, and cadmium cyanides more toxic than an equal concentration of sodium cyanide.

The toxic mechanism of cyanide is essentially an inhibition of oxygen metabolism, i.e., rendering the tissues incapable of exchanging oxygen. The cyanogen compounds are true noncumulative protoplasmic poisons. They arrest the activity of all forms of animal life. Cyanide shows a very specific type of toxic action. It inhibits the cytochrome oxidase system. This system is the one which facilitates electron transfer from reduced metabolites to molecular oxygen. The human body can convert cyanide to a non-toxic thiocyanate and eliminate it. However, if the quantity of cyanide ingested is too great at one time, the inhibition of oxygen utilization proves fatal before the detoxifying reaction reduces the cyanide concentration to a safe level.

Cyanides are more toxic to fish than to lower forms of aquatic organisms such as midge larvae, crustaceans, and mussels. Toxicity to fish is a function of chemical form and concentration, and is influenced by the rate of metabolism (temperature), the level of dissolved oxygen, and pH. In laboratory studies free cyanide concentrations ranging from 0.05 to 0.15 mg/l have been proven to be fatal to sensitive fish species including trout, bluegill, and fathead minnows. Levels above 0.2 mg/l are rapidly fatal to most fish species. Long term sublethal concentrations of cyanide as low as 0.01 mg/l have been shown to affect the ability of fish to function normally, e.g., reproduce, grow, and swim.

For the protection of human health from the toxic properties of cyanide ingested through water and through contaminated aquatic organisms, the ambient water quality criterion is determined to be 0.200 mg/l.

Persistence of cyanide in water is highly variable and depends upon the chemical form of cyanide in the water, the concentration of cyanide, and the nature of other constituents. Cyanide may be destroyed by strong oxidizing agents such as permanganate and chlorine. Chlorine is commonly used to oxidize strong cyanide solutions. Carbon dioxide and nitrogen are the products of complete oxidation. But if the reaction is not complete, the very toxic compound cyanogen chloride may remain in the treatment system and subsequently be released to the environment. Partial chlorination may occur as part of a POTW treatment, or during the disinfection treatment of surface water for drinking water preparation.

Cyanides can interfere with treatment processes in POTW, or pass through to ambient waters. At low concentrations and with acclimated microflora, cyanide may be decomposed by microorganisms in anaerobic and aerobic environments or waste treatment systems. However, data indicate that much of the cyanide introduced passes through to the POTW effluent. The mean pass-through of 14 biological plants was 71 percent. In a recent study of 41 POTW, the effluent concentrations ranged from 0.002 to 100 mg/l (mean = 2.518, standard deviation = 15.6). Cyanide also enhances the toxicity of metals commonly found in POTW effluents, including the priority pollutants cadmium, zinc, and copper.

Data for Grand Rapids, Michigan, showed a significant decline in cyanide concentrations downstream from the POTW after pretreatment regulations were put in force. Concentrations fell from 0.66 mg/l before, to 0.01 mg/l after pretreatment was required.

Lead (122). Lead is a soft, malleable, ductile, bluish-gray, metallic element, usually obtained from the minerals galena (lead sulfide, PbS), anglesite (lead sulfate, $PbSO_4$), or cerussite (lead carbonate, $PbCO_3$). Because it is usually associated with the minerals zinc, silver, copper, gold, cadmium, antimony, and arsenic, special purification methods are frequently used before and after extraction of the metal from the ore concentrate by smelting.

Lead is widely used for its corrosion resistance, sound and vibration absorption, low melting point (solders), and relatively high imperviousness to various forms of radiation. Small amounts of copper, antimony and other metals can be alloyed with lead to achieve greater hardness, stiffness, or corrosion resistance than is afforded by the pure metal. Lead compounds are used in glazes and paints. About one third of U.S. lead consumption goes into storage batteries. About half of U.S. lead consumption is from secondary lead recovery. U.S. consumption of lead is in the range of one million tons annually.

Lead ingested by humans produces a variety of toxic effects including impaired reproductive ability, disturbances in blood chemistry, neurological disorders, kidney damage, and adverse cardiovascular effects. Exposure to lead in the diet results in permanent increase in lead levels in the body. Most of the lead entering the body eventually becomes localized in the bones where it accumulates. Lead is a carcinogen or cocarcinogen in some species of experimental animals. Lead is teratogenic in experimental animals. Mutagenicity data are not available for lead.

For the protection of human health from the toxic properties of lead ingested through water and through contaminated aquatic organisms, the ambient water criterion is 0.050 mg/l.

Lead is not destroyed in POTW, but is passed through to the effluent or retained in the POTW sludge; it can interfere with POTW treatment processes and can limit the usefulness of POTW sludge for application to agricultural croplands. Threshold concentration for inhibition of the activated sludge process is 0.1 mg/l, and for the nitrification process is 0.5 mg/l. In a study of 214 POTW, median pass-through values were over 80 percent for primary plants and over 60 percent for trickling filter, activated sludge, and biological process plants. Lead concentration in POTW effluents ranged from 0.003 to 1.8 mg/l (means = 0.106 mg/l, standard deviation = 0.222).

Application of lead-containing sludge to cropland should not lead to uptake by crops under most conditions because lead is normally strongly bound by soil. However, under the unusual conditions of low pH (less than 5.5) and low concentrations of labile phosphorus, lead solubility is increased and plants can accumulate lead.

Mercury (123). Mercury is an elemental metal rarely found in nature as the free metal. Mercury is unique among metals as it remains a liquid down to about 39 degrees below zero. It is relatively inert chemically and is insoluble in water. The principal ore is cinnabar (HgS).

Mercury is used industrially as the metal and as mercurous and mercuric salts and compounds. Mercury is used in several types of batteries. Mercury released to the aqueous environment is subject to biomethylation - conversion to the extremely toxic methyl mercury.

Mercury can be introduced into the body through the skin and the respiratory system as the elemental vapor. Mercuric salts are highly toxic to humans and can be absorbed through the gastro-intestinal tract. Fatal doses can vary from 1 to 30 grams. Chronic toxicity of methyl mercury is evidenced primarily by neurological symptoms. Some mercuric salts cause death by kidney failure.

Mercuric salts are extremely toxic to fish and other aquatic life. Mercuric chloride is more lethal than copper, hexavalent chromium, zinc, nickel, and lead towards fish and aquatic life. In the food cycle, algae containing mercury up to 100 times the concentration in the surrouding sea water are eaten by fish which further concentrate the mercury. Predators that eat the fish in turn concentrate the mercury even further.

For the protection of human health from the toxic properties of mercury ingested through water and through contaminated aquatic organisms the ambient water criterion is determined to be 0.000144 mg/l.

Mercury is not destroyed when treated by a POTW, and will either pass through to the POTW effluent or be incorporated into the POTW sludge. At low concentrations it may reduce POTW removal efficiencies, and at high concentrations it may upset the POTW operation.

The influent concentrations of mercury to a POTW have been observed by the EPA to range from 0.002 to 0.24 mg/l, with a median concentration of 0.001 mg/l. Mercury has been reported in the literature to have inhibiting effects upon an activated sludge POTW at levels as low as 0.1 mg/l. At 5 mg/l of mercury, losses of COD removal efficiency of 14 to 40 percent have been reported, while at 10 mg/l loss of removal efficiency of 59 percent has been reported. Upset of an activated sludge POTW is reported in the literature to occur near 200 mg/l. The anaerobic digestion process is much less affected by the presence of mercury, with inhibitory effects being reported at 1,365 mg/l.

In a study of 22 POTW facilities having secondary treatment, the range of removal of mercury from the influent to the POTW ranged from 4 to 99 percent with median removal of 41 percent. Thus significant pass-through of mercury may occur.

In sludges, mercury content may be high if industrial sources of mercury contamination are present. Little is known about the form in which mercury occurs in sludge. Mercury may undergo biological methylation in sediments, but no methylation has been observed in soils, mud, or sewage sludge.

The mercury content of soils not receiving additions of POTW sewage sludge lie in the range from 0.01 to 0.5 mg/kg. In soils receiving POTW sludges for protracted periods, the concentration of mercury has been observed to approach 1.0 mg/kg. In the soil, mercury enters into reactions with the exchange complex of clay and organic fractions, forming both ionic and covalent bonds. Chemical and microbiological degradation of mercurials can take place side by side in the soil, and the products - ionic or molecular - are retained by organic matter and clay or may be volatilized if gaseous. Because of the high affinity between mercury and the solid soil surfaces, mercury persists in the upper layer of the soil.

Mercury can enter plants through the roots, it can readily move to other parts of the plant, and it has been reported to cause injury to plants. In many plants mercury concentrations range from 0.01 to 0.20 mg/kg, but when plants are supplied with high levels of mercury, these concentrations can exceed 0.5 mg/kg. Bioconcentration occurs in animals ingesting mercury in food.

Nickel (124). Nickel is seldom found in nature as the pure elemental metal. It is a relatively plentiful element and is widely distributed throughout the earth's crust. It occurs in marine organisms and is found in the oceans. The chief commercial ores for nickel are pentlandite [$(Fe,Ni)_9S_8$], and a lateritic ore consisting of hydrated nickel-iron-magnesium silicate.

Nickel has many and varied uses. It is used in alloys and as the pure metal. Nickel salts are used for electroplating baths. The coil coating industry uses nickel compounds as accelerators in certain conversion coating solutions. Nickel is also found as a contaminant in mineral acids.

The toxicity of nickel to man is thought to be very low, and systemic poisoning of human beings by nickel or nickel salts is almost unknown. In non-human mammals nickel acts to inhibit insulin release, depress growth, and reduce cholesterol. A high incidence of cancer of the lung and nose has been reported in humans engaged in the refining of nickel.

Nickel salts can kill fish at very low concentrations. However, nickel has been found to be less toxic to some fish than copper, zinc, and iron. Nickel is present in coastal and open ocean water at concentrations in the range of 0.0001 to 0.006 mg/l although the most common values are 0.002 - 0.003 mg/l. Marine animals contain up to 0.4 mg/l and marine plants contain up to 3 mg/l. Higher nickel concentrations have been reported to cause reduction in photosynthetic activity of the giant kelp. A low concentration was found to kill oyster eggs.

For the protection of human health based on the toxic properties of nickel ingested through water and through contaminated aquatic organisms, the ambient water criterion is determined to be 0.0134 mg/l.

Nickel is not destroyed when treated in a POTW, but will either pass through to the POTW effluent or be retained in the POTW sludge. It can interfere with POTW treatment processes and can also limit the usefulness of municipal sludge.

Nickel salts have caused inhibition of the biochemical oxidation of sewage in a POTW. In a pilot plant, slug doses of nickel significantly reduced normal treatment efficiencies for a few hours, but the plant acclimated itself somewhat to the slug dosage and appeared to achieve normal treatment efficiencies within 40 hours. It has been reported that the anaerobic digestion process is inhibited only by high concentrations of nickel, while a low concentration of nickel inhibits the nitrification process.

EPA has observed influent concentration of nickel to POTW facilities ranging from 0.01 to 3.19 mg/l, with a median of 0.33 mg/l. In a study of 190 POTW, nickel pass-through was greater than 90 percent for 82 percent of the primary plants. Median pass-through for trickling filter, activated sludge, and biological process plants was greater than 80 percent. POTW effuent concentrations ranged from 0.002 to 40 mg/l (mean = 0.410, standard deviation = 3.279).

Nickel not passed through the POTW will be incorporated into the sludge. In a recent two-year study of eight cities, four of the cities had median nickel concentrations of over 350 mg/kg, and two were over 1,000 mg/kg. The maximum nickel concentration observed was 4,010 mg/kg.

Nickel is found in nearly all soils, plants, and waters. Nickel has no known essential function in plants. In soils, nickel typically is found in the range from 10 to 100 mg/kg. Various environmental exposures to nickel appear to correlate with increased incidence of tumors in man. For example, cancer in the maxillary antrum of snuff users may result from using plant material grown on soil high in nickel.

Nickel toxicity may develop in plants from application of sewage sludge on acid soils. Nickel has reduced yields for a variety of crops, including oats, mustard, turnips, and cabbage. In one study, nickel decreased the yields of oats significantly at 100 mg/kg.

Whether nickel exerts a toxic effect on plants depends on several soil factors, the amount of nickel applied, and the contents of other metals in the sludge. Unlike copper and zinc, which are more available from inorganic sources than from sludge, nickel uptake by plants seems to be promoted by the presence of the organic matter in sludge. Soil treatments such as liming reduce the solubility of nickel. Toxicity of nickel to plants is enhanced in acidic soils.

Zinc (128). Zinc occurs abundantly in the earth's crust, concentrated in ores. It is readily refined into the pure, stable, silvery-white metal. In addition to its use in alloys, zinc is used as a protective coating on steel. It is applied by hot dipping (i.e. dipping the steel in molten zinc) or by electroplating.

Zinc can have an adverse effect on man and animals at high concentrations. Zinc at concentrations in excess of 5 mg/l causes an undesirable taste which persists through conventional treatment. For the prevention of adverse effects due to these organoleptic properties of zinc, 5 mg/l was adopted for the ambient water criterion.

Toxic concentrations of zinc compounds cause adverse changes in the morphology and physiology of fish. Lethal concentrations in the range of 0.1 mg/l have been reported. Acutely toxic concentrations induce cellular breakdown of the gills, and possibly the clogging of the gills with mucous. Chronically toxic concentrations of zinc compounds cause general enfeeblement and widespread histological changes to many organs, but not to gills. Abnormal swimming behavior has been reported at 0.04 mg/l. Growth and maturation are retarded by zinc. It has been observed that the effects of zinc poisoning may not become apparent immediately, so that fish removed from zinc-contaminated water may die as long as 48 hours after removal.

In general, salmonoids are most sensitive to elemental zinc in soft water; the rainbow trout is the most sensitive in hard waters. A complex relationship exists between zinc concentration, dissolved zinc concentration, pH, temperature, and calcium and magnesium concentration. Prediction of harmful effects has been less than reliable and controlled studies have not been extensively documented.

The major concern with zinc compounds in marine waters is not with acute lethal effects, but rather with the long-term sublethal effects of the metallic compounds and complexers. Zinc accumulates in some marine species, and marine animals contain zinc in the range of 6 to 1500 mg/kg. From the point of view of acute lethal effects, invertebrate marine animals seem to be the most sensitive organism tested.

Toxicities of zinc in nutrient solutions have been demonstrated for a number of plants. A variety of fresh water plants tested manifested harmful symptoms at concentrations of 10 mg/l. Zinc sulfate has also been found to be lethal to many plants and it could impair agricultural uses of the water.

Zinc is not destroyed when treated by POTW, but will either pass through to the POTW effluent or be retained in the POTW sludge. It can interfere with treatment processes in the POTW and can also limit the usefulness of municipal sludge.

In slug doses, and particularly in the presence of copper, dissolved zinc can interfere with or seriously disrupt the operation of POTW biological processes by reducing overall removal efficiencies, largely as a result of the toxicity of the metal to biological organisms. However, zinc solids in the form of hydroxides or sulfides do not appear to interfere with biological treatment processes, on the basis of available data. Such solids accumulate in the sludge.

The influent concentrations of zinc to POTW facilities has been observed by the EPA to range from 0.017 to 3.91 mg/l, with a median concentration of 0.33 mg/l. Primary treatment is not efficient in removing zinc; however, the microbial floc of secondary treatment readily adsorbs zinc.

In a study of 258 POTW, the median pass-through values were 70 to 88 percent for primary plants, 50 to 60 percent for trickling filter and biological process plants, and 30-40 percent for activated process plants. POTW effluent concentrations of zinc ranged from 0.003 to 3.6 mg/l (mean = 0.330, standard deviation = 0.464).

The zinc which does not pass through the POTW is retained in the sludge. The presence of zinc in sludge may limit its use on cropland. Sewage sludge contains from 72 to over 30,000 mg/kg of zinc, with 3,366 mg/kg as the mean value. These concentrations are significantly greater than those normally found in soil, which range from 0 to 195 mg/kg, with 94 mg/kg being a common level. Therefore, application of sewage sludge to soil will generally increase the concentration of zinc in the soil. Zinc can be toxic to plants, depending upon soil pH. Lettuce, tomatoes, turnips, mustard, kale, and beets are especially sensitive to zinc contamination.

Aluminum. Aluminum, a conventional pollutant, is an abundant silvery white metal comprising approximately 8.1 percent of the earth's crust. Aluminum never exists in an ionic state in nature, but rather is found as a component of several ores. The principal ore for aluminum is bauxite from which alumina (Al_2O_3) is extracted. Aluminum metal is produced by electrolysis of the alumina in the cryolite bath.

Aluminum metal is relatively corrosion resistant because it forms a protective oxide film on the surface which prevents corrosion under many conditions. Electrolytic action of other metals in contact with aluminum and strong acids and alkalis can break down the oxide layer causing rapid corrosion to occur.

Aluminum is light, malleable, ductile, possesses high thermal and electrical conductivity, and is nonmagnetic. It can be formed, machined or cast. Aluminum is used in the construction, trnasportation, and container industries and competes with iron and steel in these markets.

There is increasing evidence that dissolved aluminum has substantial adverse effects on human health. Aluminum has been implicated by several studies in the development of Alzheimer's disease (progressive senile dementia). This disease is associated with the formation of tangled bunches of nerve fibers or "neurofibrillary tangles" (NFT). Autopsy studies have shown that aluminum is present in 90 percent of the nuclei of NFT neurons. It is present in less than 6 percent of the nuclei of normal neurons. This trend is also apparent in the cytoplasm of NFT neurons, although less prominent than in the nuclei: aluminum was found in 29.4 percent of the cytoplasms of NFT neurons and 11.1 percent of the cytoplasms of normal neurons.

Brains of individuals suffering from several other neurological diseases have also displayed elevated concentrations of aluminum. These diseases include Huntington's disease, Parkinsons' disease, progressive supranuclear palsy, acoustic neuroma, and Guamanian amyotrophic lateral sclerosis (ALS).

These increased concentrations of aluminum may be a result of the development of the disease, rather than a contributing cause; however, this possibility seems less likely in light of several recent studies correlating high concentrations of aluminum in the environment to a high incidence of several of these neurological disorders. These and other studies are discussed in greater detail in the report "Aluminum: An Environmental and Health Effects Assessment," cited as a reference in this document. Although much work remains to be done on this subject, the Agency believes that the evidence points to a much broader neurotoxic role for aluminum than had previously been assumed.

In addition, mildly alkaline conditions can cause precipitation of aluminum as the hydroxide. When aluminum hydroxide precipitates in waterways or bodies of water, it can blanket the bottom, having an adverse effect on the benthos and on aquatic plant life rooted on the bottom. Aluminum hydroxide, like many precipitates, can also impair the gill action of fish when present in large amounts.

Alum, an aluminum salt with the chemical formula $Al_2(SO_4)_3 \bullet 14\ H_2O$ is used as a coagulant in municipal and industrial wastewater treatment. This form is different from dissolved aluminum and aluminum hydroxide, which are both harmful pollutants. The amount of dissolved aluminum in finished water does not generally depend upon the amount of alum used as a coagulant, unless a large excess is used. The alum is contained in the treatment sludge; very little passes through into the effluent.

Similarly, the amount of aluminum hydroxide in finished water does not depend on the amount of alum used in coagulation, but rather on the pH and the concentration of dissolved aluminum. Therefore, the use of alum as a coagulant does not result in large amounts of either aluminum or aluminum hydroxide in finished water. There are no data available on the POTW removal efficiency for the pollutant aluminum.

Fluoride. Fluoride ion (F-) is a nonconventional pollutant. Fluorine is an extremely reactive, pale yellow gas which is never found free in nature. Compounds of fluorine - fluorides - are found widely distributed in nature. The principal minerals containing fluorine are fluorspar (CaF_2) and cryolite (Na_2AlF_6). Although fluorine is produced commercially in small quantities by electrolysis of potassium bifluoride in anhydrous hydrogen fluoride, the elemental form bears little relation to the combined ion. Total production of fluoride chemicals in the U.S. is difficult to estimate because of the varied uses. Large volume usage compounds are: calcium fluoride (estimated 1,500,000 tons in U.S.) and sodium fluoraluminate (estimated 100,000 tons in U.S.). Some fluoride compounds and their uses are sodium fluoroaluminate - aluminum production; calcium fluoride - steelmaking, hydrofluoric acid production, enamel, iron foundry; boron trifluoride - organic synthesis; antimony pentafluoride - fluorocarbon production; fluoboric acid and fluoborates - electroplating; perchloryl fluoride (ClO_3F) - rocket fuel oxidizer; hydrogen fluoride - organic fluoride manufacture, pickling acid in stainless steelmaking, manufacture of aluminum fluoride; sulfur hexafluoride - insulator in high voltage transformers; polytetrafluoroethylene - inert plastic. In canmaking, hydrofluoric acid is commonly used as an etchant to provide proper surface texture for application of other materials. Sodium fluoride is used at a concentration of about 1 ppm in many public drinking water supplies to prevent tooth decay in children.

The toxic effects of fluoride on humans include severe gastroenteritis, vomiting, diarrhea, spasms, weakness, thirst, failing pulse and delayed blood coagulation. Most observations of toxic effects are made on individuals who intentionally or accidentally ingest sodium fluoride intended for use as rat poison or insecticide. Lethal doses for adults are estimated to be as low as 2.5 g. At 1.5 ppm in drinking water, mottling of tooth enamel is reported, and 14 ppm, consumed over a period of years, may lead to deposition of calcium fluoride in bone and tendons.

Fluorides found in irrigation waters in high concentrations have caused damage to certain plants exposed to these waters. Chronic fluoride poisoning of livestock has been observed. Fluoride from waters apparently does not accumulate in soft tissue to a significant degree; it is transferred to a very small extent into the milk and to a somewhat greater degree in eggs. Data for fresh water indicate that fluorides are toxic to fish.

Very few data are available on the behavior of fluoride in POTW. Under usual operating conditions in POTW, fluorides pass through into the effluent. Very little of the fluoride entering conventional primary and secondary treatment processes is removed. In one study of POTW influents conducted by the U.S. EPA, nine POTW reported concentrations of fluoride ranging from 0.7 mg/l to 1.2 mg/l, which is the range of concentrations used for fluoridated drinking water.

Manganese. Manganese is a nonconventional pollutant. It is a gray-white metal resembling iron, but is more brittle. The pure metal does not occur in nature, but must be produced by reduction of the oxide with sodium, magnesium, or aluminum, or by electrolysis. The principal ores are pyrolusite (MnO_2) and psilomelane (a complex mixture of MnO_2 and oxides of potassium, barium and other alkali and alkaline earth metals). The largest percentage of manganese used in the U.S. is in ferro-manganese alloys. A small amount goes into dry batteries and chemicals.

Manganese is not often present in natural surface waters because its hydroxides and carbonates are only sparingly soluble.

Manganese is undesirable in domestic water supplies because it causes unpleasant tastes, deposits on food during cooking, stains and discolors laundry and plumbing fixtures, and fosters the growth of some microorganisms in reservoirs, filters, and distribution systems.

Small concentrations of 0.2 to 0.3 mg/l manganese may cause buildup of heavy encrustations in piping. Excessive manganese is also undesirable in water for use in many industries, including textiles, dying, food processing, distilling, brewing, ice, and paper.

The recommended limitations for manganese in drinking water in the U.S. is 0.05 mg/l. The limit appears to be based on aesthetic and economic factors rather than physiological hazards. Most investigators regard manganese to be of no toxicological significance in drinking water at concentrations not causing unpleasant tastes. However, cases of manganese poisoning have been reported in the literature. A small outbreak of an encephalitis - like disease, with early symptoms of lethargy and edema, was traced to manganese in the drinking water in a village near Tokyo. Three persons died as a result of poisoning by well water contaminated by manganese derived from dry-cell batteries buried nearby. Excess manganese in the drinking water is also believed to be the cause of a rare disease endemic in Northeastern China.

No data were found regarding the behavior of manganese in POTW. However, one source reports that typical mineral pickup from domestic water use results in an increase in manganese concentration of 0.2 to 0.4 mg/l in a municipal sewage system. Therefore, it is expected that interference in POTW, if it occurs, would not be noted until manganese concentrations exceeded 0.4 mg/l.

Phosphorus. Phosphorus, a nonconventional pollutant, is a general term used to designate the various anions containing pentavalent phosphorus and oxygen - orthophosphate $[(PO_4)^{-3}]$, metaphosphate $[(PO_3)^{-}]$, pyrophosphate $[(P_2O_7^{-4}]$, hypophosphate $[(P_2O_6)^{-4}]$. The element phosphorus exists in several allotropic forms - red, white or yellow, and black. White phosphorus reacts with oxygen in air, igniting spontaneously. It is not found free in nature, but is widely distributed in nature. The most important commercial sources of phosphate are the apatites $[3Ca_3(PO_4)_2 \bullet CaF_2$ and $3Ca_3(PO_4)_2 \bullet CaCl_2]$. Phosphates also occur in bone and other tissue. Phosphates are essential for plant and animal life. Several millions of tons of phosphates are mined and converted for use each year in the U.S. The major form produced is phosphoric acid. The acid is then used to produce other phosphate chemicals.

The largest use for phosphates is fertilizer. Most of the U.S. production of phosphoric acid goes into that application. Phosphates are used in cleaning preparations for household and industrial applications and as corrosion inhibitors in boiler feed water and cooling towers.

Phosphates are not controlled because of toxic effects on man. Phosphates are controlled because they promote growth of algae and other plant life in aquatic environments. Such growth first becomes unsightly; if it flourishes, it eventually dies and adds to the BOD. The result can be a dead body of water. No standards or criteria appear to have been established for U.S. surface waters.

Phosphorus is one of the concerns of any POTW, because phosphates are introduced into domestic wastewaters from human body wastes and food wastes as well as household detergents. About ten percent of the phosphorus entering POTW is insoluble and is removed by primary settling. Biological treatment removes very little of the remaining phosphate. Removal is accomplished by forming an insoluble precipitate which will settle out. Alum, lime, and ferric chloride or sulfate are commonly used for this purpose. The point of addition of chemicals for phosphate removal requires careful evaluation because pH adjustment may be required, and material and capital costs differ with different removal schemes. The phosphate content of the effluent also varies according to the scheme used. There is concern about the effect of phosphate contained in sludge used for soil amendment. Phosphate is a principal ingredient of fertilizers.

Oil and Grease. Oil and grease are taken together as one pollutant parameter. This is a conventional pollutant and may include:

1. Light Hydrocarbons - These include light fuels such as gasoline, kerosene, and jet fuel, and miscellaneous solvents used for industrial processing, degreasing, or cleaning purposes. The presence of these light hydrocarbons may make the removal of other heavier oil wastes more difficult.

2. Heavy Hydrocarbons, Fuels, and Tars - These include the crude oils, diesel oils, #6 fuel oil, residual oils, slop oils, and in some cases, asphalt and road tar.

3. Lubricants and Cutting Fluids - These generally fall into two classes: non-emulsifiable oils such as lubricating oils and greases and emulsifiable oils such as water soluble oils, rolling oils, cutting oils, and drawing compounds. Emulsifiable oils may contain fat, soap or various other additives.

4. Vegetable and Animal Fats and Oils - These originate primarily from processing of foods and natural products.

These compounds can settle or float and may exist as solids or liquids depending upon factors such as method of use, production process, and temperature of wastewater.

Even small quantities of oils and grease cause troublesome taste and odor problems. Scum lines from these agents are produced on water treatment basin walls and other containers. Fish and water fowl are adversely affected by oils in their habitat. Oil emulsions may adhere to the gills of fish, causing suffocation, and the flesh of fish is tainted when microorganisms that were exposed to waste oil are eaten. Deposition of oil in the bottom sediments of water can serve to inhibit normal benthic growth. Oil and grease exhibit an oxygen demand.

Many of the organic priority pollutants will be found distributed between the oily phase and the aqueous phase in industrial wastewaters. The presence of phenols, PCBs, PAHs, and almost any other organic pollutant in the oil and grease make characterization of this parameter almost impossible. However, all of these other organics add to the objectionable nature of the oil and grease.

Levels of oil and grease which are toxic to aquatic organisms vary greatly, depending on the type and the species susceptibility. However, it has been reported that crude oil in concentrations as low as 0.3 mg/l is extremely toxic to fresh-water fish. It has been recommended that public water supply sources be essentially free from oil and grease.

Oil and grease in quantities of 100 l/sq km show up as a sheen on the surface of a body of water. The presence of oil slicks decreases the aesthetic value of a waterway.

Oil and grease is compatible with a POTW activated sludge process in limited quantity. However, slug loadings or high concentrations of oil and grease interfere with biological treatment processes. The oils coat surfaces and solid particles, preventing access of oxygen, and sealing in some microorganisms. Land spreading of POTW sludge containing oil and grease uncontaminated by toxic pollutants is not expected to affect crops grown on the treated land, or animals eating those crops.

pH. Although not a specific pollutant, pH is related to the acidity or alkalinity of a wastewater stream. It is not, however, a measure of either. The term pH is used to describe the hydrogen ion concentration (or activity) present in a given solution. Values for pH range from 0 to 14, and these numbers are the negative logarithms of the hydrogen ion concentrations. A pH of 7 indicates neutrality. Solutions with a pH above 7 are alkaline, while those solutions with a pH below 7 are acidic. The relationship of pH and acidity and alkalinity is not necessarily linear or direct. Knowledge of the water pH is useful in determining necessary measures for corrosion control, sanitation, and disinfection. Its value is also necessary in the treatment of industrial wastewaters to determine amounts of chemicals required to remove pollutants and to measure their effectiveness. Removal of pollutants, especially dissolved solids, is affected by the pH of the wastewater.

Waters with a pH below 6.0 are corrosive to water works structures, distribution lines, and household plumbing fixtures and can thus add constituents to drinking water such as iron, copper, zinc, cadmium, and lead. The hydrogen ion concentration can affect the taste of the water and at a low pH, water tastes sour. The bactericidal effect of chlorine is weakened as the pH increases, and it is advantageous to keep the pH close to 7.0. This is significant for providing safe drinking water.

Extremes of pH or rapid pH changes can exert stress conditions or kill aquatic life outright. Even moderate changes from acceptable criteria limits of pH are deleterious to some species. The relative toxicity to aquatic life of many materials is increased by changes in the water pH. For example, metallocyanide complexes can increase a thousand-fold in toxicity with a drop of 1.5 pH units.

Because of the universal nature of pH and its effect on water quality and treatment, it is selected as a pollutant parameter for the canmaking subcategory of the coil coating industry. A neutral pH range is generally desired because either extreme beyond this range has a deleterious effect on receiving waters or the pollutant nature of other wastewater constituents.

Pretreatment for regulation of pH is covered by the "General Pretreatment Regulations for Existing and New Sources of Pollution," 40 CFR 403.5. This section prohibits the discharge to a POTW of "pollutants which will cause corrosive structural damage to the POTW but in no case discharges with pH lower than 5.0 unless the works is specially designed to accommodate such discharges."

Total Suspended Solids(TSS). Suspended solids include both organic and inorganic materials. The inorganic compounds include sand, silt, and clay. The organic fraction includes such materials as grease, oil, tar, and animal and vegetable waste products. These solids may settle out rapidly, and bottom deposits are often a mixture of both organic and inorganic solids. Solids may be suspended in water for a time and then settle to the bed of the stream or lake. These solids discharged with man's wastes may be inert, slowly biodegradable materials, or rapidly decomposable substances. While in suspension, suspended solids increase the turbidity of the water, reduce light penetration, and impair the photosynthetic activity of aquatic plants.

Supended solids in water interfere with many industrial processes and cause foaming in boilers and incrustations on equipment exposed to such water, especially as the temperature rises. They are undesirable in process water used in the manufacture of steel, in the textile industry, in laundries, in dyeing, and in cooling systems.

Solids in suspension are aesthetically displeasing. When they settle to form sludge deposits on the stream or lake bed, they are often damaging to the life in the water. Solids, when transformed to sludge deposit, may do a variety of damaging things, including blanketing the stream or lake bed and thereby destroying these living spaces for benthic organisms. Organic solids use a portion or all of the dissolved oxygen available in the area. Organic materials also serve as a food source for sludgeworms and associated organisms.

Disregarding any toxic effect attributable to substances leached out by water, suspended solids may kill fish and shellfish by causing abrasive injuries and by clogging the gills and respiratory passages of various aquatic fauna. Indirectly, suspended solids are inimical to aquatic life because they screen out light, and they promote and maintain the development of noxious conditions through oxygen depletion. This results in the killing of fish and fish food organisms. Suspended solids also reduce the recreational value of the water.

Total suspended solids is a traditional pollutant which is compatible with a well-run POTW. With the exception of those components which are described elsewhere in this section, e.g., toxic metal components, this pollutant does not interfere with the operation of a POTW; however, since a considerable portion of the innocuous TSS may be inseparably bound to the constituents which do interfere with POTW operation, or produce unusable sludge, or subsequently dissolve to produce unacceptable POTW effluent, TSS may be considered a toxic waste hazard.

SPECIFIC POLLUTANTS CONSIDERED FOR REGULATION

Discussion of individual pollutant parameters selected or not selected for consideration for specific regulation is based on concentrations obtained from sampling and analysis of raw wastewater streams.

Pollutant Parameters Considered for Specific Regulation. Based on sampling results and a careful examination of the canmaking subcategory manufacturing processes and raw materials, 26 pollutant parameters were selected for consideration for specific regulation in effluent limitations and standards for this subcategory. The 26 are: 1,1,1-trichloroethane, 1,1-dichloroethane, 1,1,2,2-tetrachloroethane, bis(2-chloroethyl) ether, chloroform, 1,1-dichloroethylene, methylene chloride, pentachlorophenol, bis(2-ethylhexyl) phthalate, butyl benzyl phthalate, di-n-butyl phthalate, phenanthrene, tetrachloroethylene, toluene, chromium (total), copper, lead, nickel, zinc, aluminum, fluoride, manganese, phosphorus, oil and grease, pH, and total suspended solids. These pollutant parameters were found at treatable levels in raw wastewater from processes in this subcategory and are amenable to control by identified wastewater treatment practices.

Seven of the 14 organic compounds listed above were considered for regulation before proposal. These seven compounds (1,1,1-trichloroethane, 1,1-dichloroethylene, methylene chloride, bis(2-ethylhexyl) phthalate, butyl benzyl phthalate, di-n-butyl phthalate, and toluene) were found at maximum concentrations ranging from 0.022 mg/l to 4.10 mg/l (see Table V-11). Twenty-six quantifiable concentrations were found and 64 possible detections were noted in these samples. Following proposal, additional organics sampling was done by both the Agency (see Tables V-10 and V-19) and by a commenter (see Table V-21). These samples were evaluated to determine which organic pollutants were detected above quantifiable levels, in addition to those already selected. Seven additional organics pollutants (1,1-dichloroethane, 1,1,2,2-tetrachloroethane, bis(2-chloroethyl) ether, chloroform, pentachlorophenol, fluorene, and tetrachloroethylene) were detected at concentrations ranging from 0.012 mg/l to 0.055 mg/l. Toxic organics are found in some rolling, drawing and lubricating oils and are also in solvents and paints used in canmaking.

Chromium was detected in 15 of 15 samples of total raw wastewater from this subcategory before proposal. The maximum concentration was 5.41 mg/l. Chromium was reported at concentrations ranging from 0.05 mg/l to 36 mg/l in 39 of the 39 untreated wastewater samples in the CMI & USBA data. EPA sampling after proposal resulted in chromium analyses from 0.04 mg/l to 29.1 mg/l for five untreated wastewater samples. Chromium compounds are used in surface treatment formulations in some canwashers, and chromium is also corroded from stainless steel equipment when treatment chemicals are used. More then one-third of the concentrations are greater than those that can be achieved with specific treatment methods. Therefore, chromium is considered for specific regulation in this subcategory.

Copper was detected in 15 of 15 samples of raw wastewater from this subcategory before proposal. The maximum concentration was 0.09 mg/l. Copper was not analyzed in the CMI & USBA data. EPA sampling after proposal resulted in copper analysis at the detection limit (0.5 and 0.05 mg/l) in all samples but one which had a concentration of 0.65 mg/l. Copper is a constituent of the aluminum alloy used for canmaking. Because copper is a component of the aluminum alloy and is present in canmaking wastewaters, copper is considered for specific regulation.

Lead was detected in 7 of the 15 total raw wastewater samples analyzed before proposal. The maximum concentration was 0.052 mg/l which is below the levels considered treatable by specific methods. Following proposal lead was detected in two untreated wastewater samples. In the tramp oil sample the level was detected at a treatable level of 0.5 mg/l. Because lead is known to be a constituent in some lubricants used in canmaking, lead is considered for specific regulation.

Nickel was detected in 8 of the 15 total raw wastewater samples analyzed before proposal. The maximum concentration was 0.49 mg/l which is below the levels considered treatable. Following proposal nickel was detected in five untreated wastewater samples. The maximum concentration was 1.25 mg/l which is above the level considered treatable. Nickel can be eroded from stainless steel equipment used in canmaking. Therefore, nickel is considered for specific regulation.

Zinc was detected in 15 of 15 samples of total raw wastewater from this subcategory before proposal. The maximum concentration was 4.647 mg/l. Zinc was reported at concentrations ranging from 0.03 to 1.4 mg/l in 39 of the 39 untreated wastewater samples in the CMI & USBA data. EPA sampling after proposal resulted in zinc values from 0.060 mg/l to 3.7 mg/l in seven untreated wastewater samples. Zinc is an alloying element in aluminum coil stock used for canmaking. Some of the zinc concentrations are greater than those that can be achieved with specific treatment methods. Therefore, zinc is considered for specific regulation in this subcategory.

Aluminum was detected in all nine of the samples of the total raw wastewater analyzed before proposal. The maximum concentration was 370 mg/l. Aluminum was reported at concentrations ranging from 30 to 382 mg/l in 39 of the 39 untreated wastewater samples in the CMI & USBA data. EPA sampling after proposal resulted in aluminum values from 9.3 mg/l to 193 mg/l in seven untreated wastewater samples. Aluminum is the primary constituent of aluminum can coil stock. All of the concentrations are greater than those that can be achieved with specific treatment methods. Therefore, aluminum is considered for specific regulation in this subcategory.

Fluoride was detected in all six samples of the total raw wastewater analyzed before proposal. The maximum concentration was 18.02 mg/l. Fluoride was reported at concentrations ranging from 13.5 to 250 mg/l in 39 of the 39 untreated wastewater samples in the CMI & USBA data. EPA sampling after proposal resulted in fluoride values from 0.33 mg/l to 220 mg/l in the eight untreated wastewater samples. Fluoride ions result from the hydrofluoric acid used in the acid cleaning stage of the canwasher and sometimes in surface treating compositions. In addition, because of the almost universal use of this material in canmaking and the human health effects of concentrations well below the treatable levels, fluoride is considered for specific regulation in this subcategory.

Manganese was detected in 9 of 9 samples of raw wastewater analyzed before proposal. The maximum concentration was 5.2 mg/l. Manganese was not analyzed in the CMI & USBA data. EPA sampling after proposal resulted in manganese concentrations ranging from 0.35 mg/l to 3.4 mg/l in samples from seven plants. Manganese is a component of the aluminum alloy used for canmaking. Because manganese is a component of the aluminum alloy and is present in treatable concentrations in canmaking wastewaters, manganese is considered for specific regulation.

Phosphorus was detected in all six samples of total raw wastewater analyzed before proposal. The maximum concentration was 12.90 mg/l. Phosphorous was reported at concentrations ranging from 0.1 to 17.4 mg/l in 39 of the 39 untreated wastewater samples in the CMI & USBA data. EPA sampling after proposal resulted in phosphorus values from 0.07 mg/l to 27 mg/l in the seven untreated wastewater samples. Phosphates are used in some surface treatment compositions. In addition, because phosphates are used in many canwashers phosphorus is considered for specific regulation in this subcategory.

Oil and grease was detected in all 15 of the total raw wastewater samples analyzed before proposal. The maximum concentration was 45,094 mg/l. Oil and grease was reported at concentrations ranging from 29.3 mg/l to 1700 mg/l in 38 of the 39 untreated wastewater samples in the CMI & USBA data, using the same analytical method used for the 15 samples cited above. Oils are used for lubrication and cooling of the can stock in all seamless canmaking lines. All concentrations are greater than those that can be achieved with specific treatment methods. Therefore, oil and grease is considered for specific regulation in this subcategory.

pH ranged from 1.8 to 6.2 for the six raw wastewater samples measured before proposal. pH ranged from 2.23 to 8.00 in the 34 samples of untreated wastewaters for which pH data were submitted by CMI & USBA. pH can be controlled within the range 7.5 to 10 with specific treatment methods and is therefore considered for specific regulation in this subcategory.

Total suspended solids were present in all 15 total raw wastewater samples analyzed before proposal. The maximum concentration was 3309 mg/l. Total suspended solids was reported at concentrations ranging from 10.4 mg/l to 1440 mg/l in 39 of the 39 untreated wastewater samples in the CMI & USBA data. Suspended solids result from various forming and cleaning operations during canmaking. All the concentrations are greater than those that can be achieved with specific treatment methods. Therefore, total suspended solids are considered for specific regulation in this subcategory.

Pollutant Parameters Not Considered for Specific Regulation. A total of four pollutant parameters that were evaluated in sampling and analysis were dropped from further consideration from specific regulation in the canmaking subcategory. These parameters were found to be present in raw wastewater at levels below those usually achieved by specific treatment methods. The four are: arsenic, cadmium, cyanide, and mercury.

Arsenic was detected in 6 of the 15 total raw wastewater samples analyzed before proposal. The maximum concentration was 1.402 mg/l. This was the only concentration above the levels which are considered treatable by specific methods. Therefore, arsenic is not considered for specific regulation in this subcategory.

Cadmium was detected in 6 of the 15 total raw wastewater samples analyzed before proposal. The maximum concentration was 0.010 mg/l which is below the level considered treatable. EPA sampling after proposal resulted with no cadmium concentrations detected above the quantifiable limits. Therefore, cadmium is not considered for specific regulation in this subcategory.

Cyanide was detected in 11 of the 15 total raw wastewater samples analyzed before proposal. The maximum concentration was 0.034 mg/l which is below the level which is considered treated by specific methods. Therefore, cyanide is not considered for specific regulation in this subcategory.

Mercury was detected in 7 of the 15 total raw wastewater samples analyzed before proposal. The maximum concentration was 0.001 mg/l which is below the levels considered treatable by specific methods. Therefore, mercury is not considered for regulation in this subcategory.

Summary

Table VI-1, (page 133) presents the results of selection of priority pollutant parameters for consideration for specific regulation for the canmaking subcategory. The pollutants that were not detected are indicated by ND; those detected, but not quantifiable by NQ; those at levels considered not treatable by NT; and those considered for specific regulation by REG.

TABLE VI-1
PRIORITY POLLUTANT DISPOSITION

	Pollutant	Disposition
1.	Acenaphthene	ND
2.	Acrolein	ND
3.	Acrylonitrile	ND
4.	Benzene	NQ
5.	Benzidene	ND
6.	Carbon tetrachloride	NQ
7.	Chlorobenzene	NQ
8.	1,2,4-Trichlorobenzene	ND
9.	Hexachlorobenzene	ND
10.	1,2-Dichloroethane	ND
11.	1,1,1,-Trichloroethane	Reg
12.	Hexachloroethane	ND
13.	1,1-Dichloroethane	Reg
14.	1,1,2-Trichloroethane	ND
15.	1,1,2,2-Tetrachloroethane	Reg
16.	Chloroethane	ND
17.	Deleted	ND
18.	Bis(2-chloroethyl)ether	Reg
19.	2-Chloroethyl vinyl ether	ND
20.	2-Chloronaphthalene	ND
21.	2,4,6-Trichlorophenol	ND
22.	Parachlorometa cresol	ND
23.	Chloroform	Reg
24.	2-Chlorophenol	ND
25.	1,2-Dichlorobenzene	ND
26.	1,3-Dichlorobenzene	ND
27.	1,4-Dichlorobenzene	ND
28.	3,3-Dichlorobenzidene	ND
29.	1,1-Dichloroethylene	Reg
30.	1,2-Trans-dichloroethylene	NQ
31.	2,4-Dichlorophenol	ND
32.	1,2-Dichloropropane	ND
33.	1,2-Dichloropropylene	ND
34.	2,3-Dimethylphenol	ND
35.	2,4-Dinitrotoluene	ND
36.	2,6-Dinitrotoluene	ND
37.	1,2-Diphenylhydrazine	NQ
38.	Ethylbenzene	NQ
39.	Fluoranthene	ND
40.	4-Chlorophenyl phenyl ether	ND
41.	4-Bromophenyl phenyl ether	ND
42.	Bis(2-Chloroisopropyl)ether	ND
43.	Bis(2-Chloroethoxy)methane	ND
44.	Methylene chloride	Reg
45.	Methyl chloride	ND
46.	Methyl bromide	ND
47.	Bromoform	NQ
48.	Dichlorobromomethane	NQ
49.	Deleted	ND
50.	Deleted	ND
51	Chlorodibromomethane	NQ
52.	Hexachlorobutadiene	ND
53.	Hexachlorocyclopentadiene	ND
54.	Isophorone	ND
55.	Napthalene	ND
56.	Nitrobenzene	ND
57.	2-Nitrophenol	ND
58.	2-Nitrophenol	ND
59.	2,4-Dinitrophenol	ND
60.	4,6-Dinitro-o-cresol	ND
61.	N-nitrosodimethylamine	ND

ND - Not Detected
NQ - Not Quantifiable
NT - Not Treatable
Reg - Regulation considered

TABLE VI-1 (Continued)
PRIORITY POLLUTANT DISPOSITION

	Pollutant	Disposition
62.	N-nitrosodiphenylamine	NQ
63.	N-nitrosodi-n-propylamine	ND
64.	Pentachlorophenol	Reg
65.	Phenol	NQ
66.	Bis(2-ethylhexyl)phthalate	Reg
67.	Butyl benzyl phthalate	Reg
68.	Di-n-butyl phthalate	Reg
69.	Di-n-octyl phthalate	ND
70.	Diethyl phthalate	NQ
71.	Dimethyl phthalate	NQ
72.	1,2-Benzanthracene	NQ
73.	Benzo(a)pyrene	ND
74.	3,4-Benzofluoranthene	ND
75.	11,12-Benzofluoranthene	ND
76.	Chrysene	NQ
77.	Acenaphthylene	ND
78.	Anthracene	NQ
79.	1,12-Benzoperylene	ND
80.	Fluorene	NQ
81.	Phenanthrene	Reg
82.	1,2,5,6-Dibenzanthracene	ND
83.	Indeno(1,2,3-cd)pyrene	ND
84.	Pyrene	ND
85.	Tetrachloroethylene	Reg
86.	Toluene	Reg
87.	Trichloroethylene	NQ
88.	Vinyl chloride	ND
89.	Aldrin	ND
90.	Dieldrin	ND
91.	Chlordane	NQ
92.	4,4-DDT	NQ
93.	4,4-DDE	NQ
94.	4,4-DDD	ND
95.	Alpha-endosulfan	ND
96.	Beta-endosulfan	ND
97.	Endosulfan Sulfate	NQ
98.	Endrin	NQ
99.	Endrin aldehyde	ND
100.	Heptachlor	NQ
101.	Heptachlor epoxide	NQ
102.	Alpha-BHC	NQ
103.	Beta-BHC	NQ
104.	Gamma-BHC	NQ
105.	Delta-BHC	ND
106.	PCB-1242	ND
107.	PCB-1254	NQ
108.	PCB-1221	ND
109.	PCB-1232	ND
110.	PCB-1248	NQ
111.	PCB-1260	ND
112.	PCB-1016	ND
113.	Toxaphene	ND
114.	Antimony	ND
115.	Arsenic	NT
116.	Asbestos	ND
117.	Beryllium	ND
118.	Cadmium	NT
119.	Chromium	Reg
120.	Copper	Reg
121.	Cyanide	NT
122.	Lead	Reg
123.	Mercury	NT
124.	Nickel	Reg
125.	Selenium	ND
126.	Silver	ND
127.	Thallium	ND
128.	Zinc	Reg
129.	2,3,4,8-tetrachloro-dibenzo-p-dioxin(TCDD)	ND

ND - Not Detected
NQ - Not Quantifiable
NT - Not Treatable
Reg - Regulation Considered

SECTION VII

CONTROL AND TREATMENT TECHNOLOGY

This section describes the treatment techniques currently used or available to remove or to recover wastewater pollutants normally generated by the subcategory of the coil coating industrial point source category. Included are discussions of individual end-of-pipe treatment technologies and in-plant technologies. These treatment technologies are widely used in many industrial categories and data and information to support their effectiveness have been drawn from a similarly wide range of sources and data bases.

END-OF-PIPE TREATMENT TECHNOLOGIES

Individual recovery and treatment technologies are described which are used or are suitable for use in treating wastewater discharges from canmaking facilities. Each description includes a functional description and discussions of application and performance, advantages and limitations, operational factors (reliability, maintainability, solid waste aspects), and demonstration status. The treatment processes described include both technologies presently demonstrated within the canmaking subcategory and technologies demonstrated in treatment of similar wastes in other industries.

Canmaking wastewater streams characteristically contain significant levels of the toxic metals chromium, copper and zinc plus toxic organic pollutants which are associated with high levels of oil and grease generated during the drawing and ironing process. Additionally, the conventional pollutant parameters TSS and pH, are found as are the nonconventional pollutants aluminum, fluoride, manganese and phosphorus.

In general, these pollutants are removed by chemical precipitation and solids removal. Most of them may be effectively removed by precipitation of metal hydroxides or carbonates utilizing the reaction with lime, sodium hydroxide, or sodium carbonate. For some metals, improved removals are provided by the use of sodium sulfide or ferrous sulfide to precipitate the pollutants as sulfide compounds with very low solubilities. Preliminary treatment such as chromium reduction may also be necessary and oil removal using skimming, emulsion breaking, dissolved air flotation or a combination of these technologies may be applied before metals removal. Fluoride and phosphorus are removed primarily as calcium salts, requiring lime as the precipitation reagent.

Discussion of end-of-pipe treatment technologies is divided into three parts: the major technologies; the effectiveness of major technologies; and minor end-of-pipe technologies.

MAJOR TECHNOLOGIES

In Sections IX, X, XI and XII, the rationale for selecting treatment systems is discussed. The individual technologies or unit operations used in the systems are described here. The major end-of-pipe technologies for treating canmaking wastewaters are: (1) chemical reduction of hexavalent chromium, (2) chemical precipitation of dissolved metals, (3) cyanide precipitation, (4) granular bed filtration, (5) pressure filtration, (6) settling of suspended solids, and (7) skimming for oil removal. for oil removal. In practice, precipitation of metals and settling of the resulting precipitates is often a unified two-step operation. Suspended solids originally present in raw wastewaters are not appreciably affected by the precipitation operation and are removed with the precipitated metals in the settling operations. Settling operations can be evaluated independently of hydroxide or other chemical precipitation operations, but hydroxide and other chemical precipitation operations can only be evaluated in combination with a solids removal operation.

1. Chemical Reduction Of Chromium

Description of the Process. Reduction is a chemical reaction in which electrons are transferred to the chemical being reduced from the chemical initiating the transfer (the reducing agent). Sulfur dioxide, sodium bisulfite, sodium metabisulfite, and ferrous sulfate form strong reducing agents in aqueous solution and are often used in industrial waste treatment facilities for the reduction of hexavalent chromium to the trivalent form. The reduction allows removal of chromium from solution in conjunction with other metallic salts by alkaline precipitation. Hexavalent chromium is not precipitated as the hydroxide.

Gaseous sulfur dioxide is a widely used reducing agent and provides a good example of the chemical reduction process. Reduction using other reagents is chemically similar. The reactions involved may be illustrated as follows:

$$3\ SO_2 + 3\ H_2O \text{ ----> } 3\ H_2SO_3$$

$$3\ H_2SO_3 + 2H_2CrO_4 \text{ ----> } Cr_2(SO_4)_3 + 5\ H_2O$$

The above reaction is favored by low pH. A pH of from 2 to 3 is normal for situations requiring complete reduction. At pH levels above 5, the reduction rate is slow. Oxidizing agents such as dissolved oxygen and ferric iron interfere with the reduction process by consuming the reducing agent.

A typical treatment consists of 45 minutes retention in a reaction tank. The reaction tank has an electronic recorder-controller device to control process conditions with respect to pH and oxidation reduction potential (ORP). Gaseous sulfur dioxide is metered to the reaction tank to maintain the ORP within the range of 250 to 300 millivolts. Sulfuric acid is added to maintain a pH level of from 1.8 to 2.0. The reaction tank is equipped with a propeller agitator designed to provide approximately one turnover per minute. Figure VII-13 (page 249) shows a continuous chromium reduction system.

Application and Performance. It may be necessary in the canmaking subcategory to treat wastewater from cans which have been surface treated with a chromium conversion coating. A study of an operational wastewater treatment facility chemically reducing hexavalent chromium has shown that a 99.7 percent reduction efficiency is easily achieved. Final concentrations of 0.05 mg/l are readily attained, and concentrations of 0.01 mg/l are considered to be attainable by properly maintained and operated equipment. Because the chemical systems used for chromium conversion coatings are similar, the chemical reduction of chromium is applicable to canmaking wastewaters.

Advantages and Limitations. The major advantage of chemical reduction to reduce hexavalent chromium is that it is a fully proven technology based on many years of experience. Operation at ambient conditions results in low energy consumption, and the process, especially when using sulfur dioxide, is well suited to automatic control. Furthermore, the equipment is readily obtainable from many suppliers, and operation is straightforward.

One limitation of chemical reduction of hexavalent chromium is that for high concentrations of chromium, the cost of treatment chemicals may be prohibitive. When this situation occurs, other treatment techniques are likely to be more economical. Chemical interference by oxidizing agents is possible in the treatment of mixed wastes, and the treatment itself may introduce pollutants if not properly controlled. Storage and handling of sulfur dioxide is somewhat hazardous.

Operational Factors. Reliability: Maintenance consists of periodic removal of sludge. The frequency of removal is a function of the input concentrations of detrimental constituents.

Solid Waste Aspects: Pretreatment to eliminate substances which will interfere with the process may often be necessary. This process produces trivalent chromium which can be controlled by further treatment. However, small amounts of sludge collected due to minor shifts in the solubility of the contaminants. This sludge can be processed by the main sludge treatment equipment.

Demonstration Status. The reduction of chromium waste by sulfur dioxide or sodium bisulfite is a classic process and is used by numerous plants which have hexavalent chromium compounds in wastewaters from operations such as electroplating, conversion coating, and noncontact cooling. Four canmaking plants reported practicing chromium reduction.

2. Chemical Precipitation

Dissolved toxic metal ions and certain anions may be chemically precipitated for subsequent removal by physical means such as sedimentation, filtration, or centrifugation. Several reagents are commonly used to effect this precipitation:

1) Alkaline compounds such as lime or sodium hydroxide may be used to precipitate many toxic metal ions as metal hydroxides. Lime also may precipitate phosphates as calcium phosphate and fluorides as calcium fluoride.

2) Both "soluble" sulfides such as hydrogen sulfide or sodium sulfide and "insoluble" sulfides such as ferrous sulfide may be used to precipitate many heavy metal ions as metal sulfides.

3) Ferrous sulfate, zinc sulfate or both (as is required) may be used to precipitate cyanide as a ferro or zinc ferricyanide complex.

4) Carbonate precipitates may be used to remove metals either by direct precipitation using a carbonate reagent such as calcium carbonate or by converting hydroxides into carbonates using carbon dioxide.

These treatment chemicals may be added to a flash mixer or rapid mix tank, to a presettling tank, or directly to a clarifier or other settling device. Because metal hydroxides tend to be colloidal in nature, coagulating agents may also be added to facilitate settling. After the solids have been removed, final pH adjustment may be required to reduce the high pH created by the alkaline treatment chemicals.

Chemical precipitation as a mechanism for removing metals from wastewater is a complex process of at least two steps - precipitation of the unwanted metals and removal of the precipitate. Some small amount of metal will remain dissolved in the wastewater after precipitation is complete. The amount of residual dissolved metal depends on the treatment chemicals used and related factors. The effectiveness of this method of removing any specific metal depends on the fraction of the specific metal in the raw wastewater (and hence in the precipitate) and the effectiveness of suspended solids removal. In specific instances, a sacrifical ion such as iron or aluminum may be added to aid in the precipitation process and reduce the fraction of a specific metal in the precipitate.

Application and Performance. Chemical precipitation is used in canmaking for precipitation of dissolved metals. It can be used to remove metal ions such as antimony, arsenic, beryllium, cadmium, chromium, copper, lead, mercury, zinc, aluminum, cobalt iron, manganese, molybden and tin. The process is also applicable to any substance that can be transformed into an insoluble form such as fluorides, phosphates, soaps, sulfides and others. Because it is simple and effective, chemical precipitation is extensively used for industrial wastewater treatment.

The performance of chemical precipitation depends on several variables. The most important factors affecting precipitation effectiveness are:

1. Maintenance of an alkaline pH throughout the precipitation reaction and subsequent settling;

2. Addition of a sufficient excess of treatment ions to drive the precipitation reaction to completion;

3. Addition of an adequate supply of sacrifical ions (such as iron or aluminum) to ensure precipitation and removal of specific target ions; and

4. Effective removal of precipitated solids (see appropriate technologies discussed under "Solids Removal").

Control of pH. Irrespective of the solids removal technology employed, proper control of pH is absolutely essential for favorable performance of precipitation-sedimentation technologies. This is clearly illustrated by solubility curves for selected metal hydroxides and sulfides shown in Figure VII-1 (page 237), and by plotting effluent zinc concentrations against pH as shown in Figure VII-3 (page 239). Figure VII-3 was obtained from Development Document for the Proposed Effluent Limitations Guidelines and New Source Performance Standards for the Zinc Segment of Nonferrous Metals Manufacturing Point Source Category, U.S. E.P.A., EPA 440/1-74/033, November, 1974. Figure VII-3 was plotted from the sampling data from several facilities with metal finishing operations. It is partially illustrated by data obtained from 3 consecutive days of sampling at one metal processing plant (47432) as displayed in Table VII-1 (page 216). Flow through this system is approximately 49,263 l/hr (13,000 gal/hr).

This treatment system uses lime precipitation (pH adjustment) followed by coagulant addition and sedimentation. Samples were taken before (in) and after (out) the treatment system. The best treatment for removal of copper and zinc was achieved on day one, when the pH was maintained at a satisfactory level. The poorest treatment was found on the second day, when the pH slipped to an unacceptably low level; intermediate values were achieved on the third day when pH values were less than desirable but in between those of the first and second days.

Sodium hydroxide is used by one facility (plant 439) for pH adjustment and chemical precipitation, followed by settling (sedimentation and a polishing lagoon) of precipitated solids. Samples were taken prior to caustic addition and following the polishing lagoon. Flow through the system is approximately 22,700 l/hr (6,000 gal/hr) displayed in Table VII-2 (page 216). These data for this plant indicate that the system was operated efficiently. Effluent pH was controlled within the range of 8.6-9.3, and, while raw waste loadings were not unusually high, most toxic metals were removed to very low concentrations.

Lime and sodium hydroxide (combined) are sometimes used to precipitate metals. Data developed from plant 40063, a facility with a metal bearing wastewater, exemplify efficient operation of a chemical precipitation and settling system. Table VII-3 (page 217) shows sampling data from this system, which uses lime and sodium hydroxide for pH adjustment and chemical precipitation, polyelectrolyte flocculant addition, and sedimentation. Samples were taken of the raw waste influent to the system and of the clarifier effluent. Flow through the system is approximately 19,000 l/hr (5,000 gal/hr).

At this plant, effluent TSS levels were below 15 mg/l on each day, despite average raw waste TSS concentrations of over 3500 mg/l. Effluent pH was maintained at approximately 8, lime addition was sufficient to precipitate the dissolved metal ions, and the flocculant addition and clarifier retention served to remove effectively the precipitated solids.

Sulfide Precipitation is sometimes used to precipitate metals resulting in improved metals removals. Most metal sulfides are less soluble than hydroxides and the precipitates are frequently more dependably removed from water. Solubilities for selected metal hydroxide, carbonate and sulfide precipitates are shown in

Table VII-4 (page 217) (Source: Lange's Handbook of Chemistry). Sulfide precipitation is particularly effective in removing specific metals such as silver and mercury. Sampling data from three industrial plants using sulfide precipitation appear in Table VII-5 (page 218). In all cases except iron, effluent concentrations are below 0.1 mg/l and in many cases below 0.01 mg/l for the three plants studied.

Sampling data from several chlorine-caustic manufacturing plants using sulfide precipitation demonstrate effluent mercury concentrations varying between 0.009 and 0.03 mg/l. As shown in Figure VII-1, the solubilities of PbS and Ag_2S are lower at alkaline pH levels than either the corresponding hydroxides or other sulfide compounds. This implies that removal performance for lead and silver sulfides should be comparable to or better than that for the heavy metal hydroxides. Bench scale tests on several types of metal finishing and manufacturing wastewater indicate that metals removal to levels of less than 0.05 mg/l and in some cases less than 0.01 mg/l are common in systems using sulfide precipitation followed by clarification. Some of the bench scale data, particularly in the case of lead, do not support such low effluent concentrations. However, lead is consistently removed to very low levels (less than 0.02 mg/l) in systems using hydroxide and carbonate precipitation and sedimentation.

Of particular interest is the ability of sulfide to precipitate hexavalent chromium (Cr^{+6}) without prior reduction to the trivalent state as is required in the hydroxide process. When ferrous sulfide is used as the precipitant, iron and sulfide act as reducing agents for the hexavalent chromium according to the reaction:

$$CrO_3 + FeS + 3H_2O \text{ ----> } Fe(OH)_3 + Cr(OH)_3 + S$$

The sludge produced in this reaction consists mainly of ferric hydroxides, chromic hydroxides and various metallic sulfides. Some excess hydroxyl ions are generated in this process, possibly requiring a downward re-adjustment of pH.

Based on the available data, Table VII-6 (page 219) shows the minimum reliably attainable effluent concentrations for sulfide precipitation-sedimentation systems. These values are used to calculate performance predictions of sulfide precipitation-sedimentation systems.

Carbonate Precipitation is sometimes used to precipitate metals, especially where precipitated metals values are to be recovered. The solubility of most metal carbonates is intermediate between hydroxide and sulfide solubilities; in addition, carbonates form easily filtered precipitates.

Carbonate ions appear to be particularly useful in precipitating lead and antimony. Sodium carbonate has been observed being added at treatment to improve lead precipitation and removal in some industrial plants. The lead hydroxide and lead carbonate solubility curves displayed in Figure VII-2 (page 238) (Source: "Heavy Metals Removal," by Kenneth Lanovette, Chemical Engineering/Deskbook Issue, Oct. 17, 1977) demonstrate this phenomenon.

Co-precipitation With Iron. The presence of substantial quantities of iron in metal bearing wastewaters before treatment has been shown to improve the removal of toxic metals. In some cases this iron is an integral part of the industrial wastewater; in other cases iron is deliberately added as a pre or first step of treatment. The iron functions to improve toxic metal removal by three mechanisms: the iron co-precipitates with toxic metals forming a stable precipitate which desolubilizes the toxic metal; the iron improves the settleability of the precipitate; and the large amount of iron reduces the fraction of toxic metal in the precipitate. Co-precipitation with iron has been practiced for many years - incidentally when iron was a substantial consitutent of raw wastewater and intentionally when iron salts were added as a coagulant aid. Aluminum or mixed iron-aluminum salt also have been used.

Co-precipitation using large amounts of ferrous iron salts is known as ferrite co-precipitation because magnetic iron oxide or ferrite is formed. The addition of ferrous salts (sulfate) is followed by alkali precipitation and air oxidation. The resultant precipitate is easily removed by filtration and may be removed magnetically. Data illustrating the performance of ferrite co-precipitation is shown in Table VII-7 (page 220).

Advantages and Limitations. Chemical precipitation has proven to be an effective technique for removing many pollutants from industrial wastewater. It operates at ambient conditions and is well suited to automatic control. The use of chemical precipitation may be limited because of interference by chelating agents, because of possible chemical interference of mixed wastewaters and treatment chemicals, or because of the potentially hazardous situation involved with the storage and handling of those chemicals. Lime is usually added as a slurry when used in hydroxide precipitation. The slurry must be kept well mixed and the addition lines periodically checked to prevent blocking of the lines, which may result from a buildup of solids. Also, hydroxide precipitation usually makes recovery of the precipitated metals difficult, because of the heterogeneous nature of most hydroxide sludges.

The major advantage of the sulfide precipitation process is that the extremely low solubility of most metal sulfides promotes very high metal removal efficiencies; the sulfide process also has the ability to remove chromates and dichromates without preliminary reduction of the chromium to its trivalent state. In addition, sulfide can precipitate metals complexed with most complexing agents. The process demands care, however, in maintaining the pH of the solution at approximately 10 in order to prevent the generation of toxic hydrogen sulfide gas. For this reason, ventilation of the treatment tanks may be a necessary precaution in most installations. The use of insoluble sulfides reduces the problem of hydrogen sulfide evolution. As with hydroxide precipitation, excess sulfide ion must be present to drive the precipitation reaction to completion. Since the sulfide ion itself is toxic, sulfide addition must be carefully controlled to maximize heavy metals precipitation with a minimum of excess sulfide to avoid the necessity of additional wastewater treatment. At very high excess sulfide levels and high pH, soluble mercury-sulfide compounds may also be formed. Where excess sulfide is present, aeration of the effluent stream can aid in oxidizing residual sulfide to the less harmful sodium sulfate (Na_2SO_4). The cost of sulfide precipitants is high in comparison with hydroxide precipitants, and disposal of metallic sulfide sludges may pose problems. An essential element in effective sulfide precipitation is the removal of precipitated solids from the wastewater and proper disposal in an appropriate site. Sulfide precipitation will also generate a higher volume of sludge, than hydroxide precipitation, resulting in higher disposal and dewatering costs. This is especially true when ferrous sulfide is used as the precipitant.

Sulfide precipitation may be used as a polishing treatment after hydroxide precipitation-sedimentation. This treatment configuration may provide the better treatment effectiveness of sulfide precipitation while minimizing the variability caused by changes in raw wastewater composition and reducing the amount of sulfide precipitant required.

Operational Factors. Reliability: Alkaline chemical precipitation is highly reliable, although proper monitoring and control are required. Sulfide precipitation systems provide similar reliability.

Maintainability: The major maintenance needs involve periodic upkeep of monitoring equipment, automatic feeding equipment, mixing equipment, and other hardware. Removal of accumulated sludge is necessary for efficient operation of precipitation-sedimentation systems.

Solid Waste Aspects: Solids which precipitate out are removed in a subsequent treatment step. Ultimately, these solids require proper disposal.

Demonstration Status. Chemical precipitation of metal hydroxides is a classic wastewater treatment technology used by most industrial wastewater treatment systems. Chemical precipitation of metals in the carbonate form alone has been found to be feasible and is commercially used to permit metals recovery and water reuse. Full scale commercial sulfide precipitation units are in operation at numerous installations. As noted earlier, sedimentation to remove precipitates is discussed separately.

Use in Canmaking Plants. Chemical precipitation equipment is in place at 42 canmaking plants.

3. Cyanide Precipitation

Cyanide precipitation, although a method for treating cyanide in wastewaters, does not destroy cyanide. The cyanide is retained in the sludge that is formed. Reports indicate that during exposure to sunlight the cyanide complexes can break down and form free cyanide. For this reason the sludge from this treatment method must be disposed of carefully.

Cyanide may be precipitated and settled out of wastewaters by the addition of zinc sulfate or ferrous sulfate. In the presence of iron, cyanide will form extremely stable cyanide complexes. The addition of zinc sulfate or ferrous sulfate forms zinc ferrocyanide or ferro and ferricyanide complexes.

Adequate removal of the precipitated cyanide requires that the pH must be kept at 9.0 and an appropriate retention time be maintained. A study has shown that the formation of the complex is very dependent on pH. At pH's of 8 and 10 the residual cyanide concentrations measured are twice those of the same reaction carried out at a pH of 9. Removal efficiencies also depend heavily on the retention time allowed. The formation of the complexes takes place rather slowly. Depending upon the excess amount of zinc sulfate or ferrous sulfate added, at least a 30 minute retention time should be allowed for the formation of the cyanide complex before continuing on to the clarification stage.

One experiment with an initial concentration of 10 mg/l of cyanide showed that 98 percent of the cyanide was complexed ten minutes after the addition of ferrous sulfate at twice the theoretical amount necessary. Interference from other metal ions, such as cadmium, might result in the need for longer retention times.

Table VII-8 (page 220) presents cyanide precipitation data from three coil coating plants. A fourth plant was visited for the purpose of observing plant testing of the cyanide precipitation system. Specific data from this facility are not included because: (1) the pH was usually well below the optimum level of 9.0; (2) the historical treatment data were not obtained using the standard cyanide analysis procedure; and (3) matched input-output data were not made available by the plant. Scanning the available data indicates that the raw waste CN level was in the range of 25.0; the pH 7.5; and treated CN level was from 0.1 to 0.2.

The concentrations are those of the stream entering and leaving the treatment system. Plant 1057 allowed a 27 minute retention time for the formation of the complex. The retention time for the other plants is not known. The data suggest that over a wide range of cyanide concentration in the raw wastewater, the concentration of cyanide can be reduced in the effluent stream to under 0.15 mg/l.

Application and Performance. Cyanide precipitation can be used when cyanide destruction is not feasible because of the presence of cyanide complexes which are difficult to destroy. Effluent concentrations of cyanide well below 0.15 mg/l are possible.

Advantages and Limitations. Cyanide precipitation is an inexpensive method of treating cyanide. Problems may occur when metal ions interfere with the formation of the complexes.

Demonstration Status: Cyanide precipitation is used in at least six coil coating plants but is not reported to be used at any canmaking plants.

4. Granular Bed Filtration

Filtration occurs in nature as the surface ground waters are cleansed by sand. Silica sand, anthracite coal, and garnet are common filter media used in water treatment plants. These are usually supported by gravel. The media may be used singly or in combination. The multi-media filters may be arranged to maintain relatively distinct layers by virtue of balancing the forces of gravity, flow, and buoyancy on the individual particles. This is accomplished by selecting appropriate filter flow rates (gpm/sq-ft), media grain size, and density.

Granular bed filters may be classified in terms of filtration rate, filter media, flow pattern, or method of pressurization. Traditional rate classifications are slow sand, rapid sand, and high rate mixed media. In the slow sand filter, flux or hydraulic loading is relatively low, and removal of collected solids to clean the filter is therefore relatively infrequent. The filter is often cleaned by scraping off the inlet face (top) of the sand bed. In the higher rate filters, cleaning is frequent and is accomplished by a periodic backwash, opposite to the direction of normal flow.

A filter may use a single medium such as sand or diatomaceous earth, but dual and mixed (multiple) media filters allow higher flow rates and efficiencies. The dual media filter usually consists of a fine bed of sand under a coarser bed of anthracite coal. The coarse coal removes most of the influent solids, while the fine sand performs a polishing function. At the end of the backwash, the fine sand settles to the bottom because it is denser than the coal, and the filter is ready for normal operation. The mixed media filter operates on the same principle, with the finer, denser media at the bottom and the coarser, less dense media at the top. The usual arrangement is garnet at the bottom (outlet end) of the bed, sand in the middle, and anthracite coal at the top. Some mixing of these layers occurs and is, in fact, desirable.

The flow pattern is usually top-to-bottom, but other patterns are sometimes used. Upflow filters are sometimes used, and in a horizontal filter the flow is horizontal. In a biflow filter, the influent enters both the top and the bottom and exits laterally. The advantage of an upflow filter is that with an upflow backwash the particles of a single filter medium are distributed and maintained in the desired coarse-to-fine (bottom-to-top) arrangement. The disadvantage is that the bed tends to become fluidized, which ruins filtration efficiency. The biflow design is an attempt to overcome this problem.

The classic granular bed filter operates by gravity flow; however, pressure filters are fairly widely used. They permit higher solids loadings before cleaning and are advantageous when the filter effluent must be pressurized for further downstream treatment. In addition, pressure filter systems are often less costly for low to moderate flow rates.

Figure VII-14 (page 250) depicts a high rate, dual media, gravity downflow granular bed filter, with self-stored backwash. Both filtrate and backwash are piped around the bed in an arrangement that permits gravity upflow of the backwash, with the stored filtrate serving as backwash. Addition of the indicated coagulant and polyelectrolyte usually results in a substantial improvement in filter performance.

Auxiliary filter cleaning is sometimes employed in the upper few inches of filter beds. This is conventionally referred to as surface wash and is accomplished by water jets just below the surface of the expanded bed during the backwash cycle. These jets enhance the scouring action in the bed by increasing the agitation.

An important feature for successful filtration and backwashing is the underdrain. This is the support structure for the bed. The underdrain provides an area for collection of the filtered water without clogging from either the filtered solids or the media grains. In addition, the underdrain prevents loss of the media with the water, and during the backwash cycle it provides even flow distribution over the bed. Failure to dissipate the velocity head during the filter or backwash cycle will result in bed upset and the need for major repairs.

Several standard approaches are employed for filter underdrains. The simplest one consists of a parallel porous pipe imbedded under a layer of coarse gravel and manifolded to a header pipe for effluent removal. Other approaches to the underdrain system are known as the Leopold and Wheeler filter bottoms. Both of these incorporate false concrete bottoms with specific porosity configurations to provide drainage and velocity head dissipation.

Filter system operation may be manual or automatic. The filter backwash cycle may be on a timed basis, a pressure drop basis with a terminal value which triggers backwash, or a solids carry-over basis from turbidity monitoring of the outlet stream. All of these schemes have been used successfully.

Application and Performance. Wastewater treatment plants often use granular bed filters for polishing after clarification, sedimentation, or other similar operations. Granular bed filtration thus has potential application to nearly all industrial plants. Chemical additives which enhance the upstream treatment equipment may or may not be compatible with or enhance the filtration process. Normal operating flow rates for various types of filters are as follows:

Slow Sand	2.04 - 5.30 l/sq m-hr
Rapid Sand	40.74 - 51.48 l/sq m-hr
High Rate Mixed Media	81.48 - 122.22 l/sq m-hr

Suspended solids are commonly removed from wastewater streams by filtering through a deep 0.3-0.9 m (1-3 feet) granular filter bed. The porous bed formed by the granular media can be designed to remove practically all suspended particles. Even colloidal suspensions (roughly 1 to 100 microns) are adsorbed on the surface of the media grains as they pass in close proximity in the narrow bed passages.

Properly operated filters following some pretreatment to reduce suspended solids below 200 mg/l should produce water with less than 10 mg/l TSS. For example, multimedia filters produced the effluent qualities shown in Table VII-9 (page 221).

The principal advantages of granular bed filtration are its comparatively (to other filters) low initial and operating costs, reduced land requirements over other methods to achieve the same level of solids removal, and elimination of chemical additions to the discharge stream. However, the filter may require pretreatment if the solids level is high (over 100 mg/l). Operator training must be somewhat extensive due to the controls and periodic backwashing involved, and backwash must be stored and dewatered for economical disposal.

Operational Factors. Reliability: The recent improvements in filter technology have significantly improved filtration reliability. Control systems, improved designs, and good operating procedures have made filtration a highly reliable method of water treatment.

Maintainability: Deep bed filters may be operated with either manual or automatic backwash. In either case, they must be periodically inspected for media attrition, partial plugging, and leakage. Where backwashing is not used, collected solids must be removed by shoveling, and filter media must be at least partially replaced.

Solid Waste Aspects: Filter backwash is generally recycled within the wastewater treatment system, so that the solids ultimately appear in the clarifier sludge stream for subsequent dewatering. Alternatively, the backwash stream may be dewatered directly or, if there is no backwash, the collected solids may be disposed of in a suitable landfill. In either of these situations there is a solids disposal problem similar to that of clarifiers.

Demonstration Status. Deep bed filters are in common use in municipal treatment plants. Their use in polishing industrial clarifier effluent is increasing, and the technology is proven and conventional. Granular bed filtration is used in many manufacturing plants. As noted previously, however, little data is available characterizing the effectiveness of filters presently in use within the industry. However, 3 canmaking plants have granular bed filtration equipment in-place as polishing filters before discharging treated wastewater.

5. Pressure Filtration

Pressure filtration works by pumping the liquid through a filter material which is impenetrable to the solid phase. The positive pressure exerted by the feed pumps or other mechanical means provides the pressure differential which is the principal driving force. Figure VII-15 (page 251) represents the operation of one type of pressure filter.

A typical pressure filtration unit consists of a number of plates or trays which are held rigidly in a frame to ensure alignment and which are pressed together between a fixed end and a traveling end. On the surface of each plate is mounted a filter made of cloth or a synthetic fiber. The feed stream is pumped into the unit and passes through holes in the trays along the length of the press until the cavities or chambers between the trays are completely filled. The solids are then entrapped, and a cake begins to form on the surface of the filter material. The water passes through the fibers, and the solids are retained.

At the bottom of the trays are drainage ports. The filtrate is collected and discharged to a common drain. As the filter medium becomes coated with sludge, the flow of filtrate through the filter drops sharply, indicating that the capacity of the filter has been exhausted. The unit must then be cleaned of the sludge. After the cleaning or replacement of the filter media, the unit is again ready for operation.

Application and Performance. Pressure filtration is used in coil coating for sludge dewatering and also for direct removal of precipitated and other suspended solids from wastewater. Because dewatering is such a common operation in treatment systems, pressure filtration is a technique which can be found in many industries concerned with removing solids from their waste stream.

In a typical pressure filter, chemically preconditioned sludge detained in the unit for one to three hours under pressures varying from 5 to 13 atmospheres exhibited final solids content between 25 and 50 percent.

Advantages and Limitations. The pressures which may be applied to a sludge for removal of water by filter presses that are currently available range from 5 to 13 atmospheres. As a result, pressure filtration may reduce the amount of chemical pretreatment required for sludge dewatering. Sludge retained in the form of the filter cake has a higher percentage of solids than that from centrifuge or vacuum filter. Thus, it can be easily accommodated by materials handling systems.

As a primary solids removal technique, pressure filtration requires less space than clarification and is well suited to streams with high solids loadings. The sludge produced may be disposed without further dewatering, but the amount of sludge is increased by the use of filter precoat materials (usually diatomaceous earth). Also, cloth pressure filters often do not achieve as high a degree of effluent clarification as clarifiers or granular media filters.

Two disadvantages associated with pressure filtration in the past have been the short life of the filter cloths and lack of automation. New synthetic fibers have largely offset the first of these problems. Also, units with automatic feeding and pressing cycles are now available.

For larger operations, the relatively high space requirements, as compared to those of a centrifuge, could be prohibitive in some situations.

Operational Factors. Reliability: With proper pretreatment, design, and control, pressure filtration is a highly dependable system.

Maintainability: Maintenance consists of periodic cleaning or replacement of the filter media, drainage grids, drainage piping, filter pans, and other parts of the system. If the removal of the sludge cake is not automated, additional time is required for this operation.

Solid Waste Aspects: Because it is generally drier than other types of sludges, the filter sludge cake can be handled with relative ease. One of several accepted procedures may be used to dispose of the accumulated sludge, depending on its chemical composition. The levels of toxic metals present in sludge from treating canmaking wastewater necessitate proper disposal.

Demonstration Status. Pressure filtration is a commonly used technology in a great many commercial applications.

6. Settling

Settling is a process which removes solid particles from a liquid matrix by gravitational force. This is done by reducing the velocity of the feed stream in a large volume tank or lagoon so that gravitational settling can occur. Figure VII-16 (page 252) shows two typical settling devices.

Settling is often preceded by chemical precipitation which converts dissolved pollutants to solid form and by coagulation which enhances settling by coagulating suspended precipitates into larger, faster settling particles.

If no chemical pretreatment is used, the wastewater is fed into a tank or lagoon where it loses velocity and the suspended solids are allowed to settle out. The rate of settling is defined by an engineering equation known as Stokes' Law. Long retention times are generally required. Accumulated sludge can be collected either periodically or continuously and either manually or mechanically. Simple settling, however, may require excessively large catchments, and long retention times (days as compared with hours) to achieve high removal efficiencies. Because of this, addition of settling aids such as alum or polymeric flocculants is often economically attractive.

In practice, chemical precipitation often precedes settling, and inorganic coagulants or polyelectrolytic flocculants are usually added as well. Common coagulants include sodium sulfate, sodium aluminate, ferrous or ferric sulfate, and ferric chloride. Organic polyelectrolytes vary in structure, but all usually form larger floc particles than coagulants used alone.

Following this pretreatment, the wastewater can be fed into a holding tank or lagoon for settling, but is more often piped into a clarifier for the same purpose. A clarifier reduces space requirements, reduces retention time, and increases solids removal efficiency. Conventional clarifiers generally consist of a circular or rectangular tank with a mechanical sludge collecting device or with a sloping funnel-shaped bottom designed for sludge collection. In advanced settling devices inclined plates, slanted tubes, or a lamellar network may be included within the clarifier tank in order to increase the effective settling area, increasing capacity. A fraction of the sludge stream is often recirculated to the inlet, promoting formation of a denser sludge.

Application and Performance. Settling and clarification are used in the canmaking industry to remove precipitated metals. Settling can be used to remove most suspended solids in a particular waste stream; thus it is used extensively by many different industrial wastewater treatment facilities. Because most metal ion pollutants are readily converted to solid metal hydroxide precipitates, settling is of particular use in those industries associated with metal production, metal finishing, metal working, and any other industry with high concentrations of metal ions in their wastewaters. In addition to toxic metals, suitably precipitated materials effectively removed by settling include aluminum, iron, manganese, cobalt, antimony, beryllium, molybdenum, fluoride, phosphate, and many others.

A properly operating settling system can efficiently remove suspended solids, precipitated metal hydroxides, and other impurities from wastewater. The performance of the process depends on a variety of factors, including the density and particle size of the solids, the effective charge on the suspended particles, and the types of chemicals used in pretreatment. The site of flocculant or coagulant addition also may significantly influence the effectiveness of clarification. If the flocculant is subjected to too much mixing before entering the clarifier, the complexes may be sheared and the settling effectiveness diminished. At the same time, the flocculant must have sufficient mixing and reaction time in order for effective set-up and settling to occur. Plant personnel have observed that the line or trough leading into the clarifier is often the most efficient site for flocculant addition. The performance of simple settling is a function of movement rate, retention time, particle size and density, and the surface area of the basin.

The data displayed in Table VII-10 (page 221) indicate suspended solids removal efficiencies in settling systems.

The mean effluent TSS concentration obtained by the plants shown in Table VII-10 is 10.1 mg/l. Influent concentrations averaged 838 mg/l. The maximum effluent TSS value reported is 23 mg/l. These plants all use alkaline pH adjustment to precipitate metal hydroxides, and most add a coagulant or flocculant prior to settling.

Advantages and Limitations. The major advantage of simple settling is its simplicity as demonstrated by the gravitational settling of solid particulate waste in a holding tank or lagoon. The major problem with simple settling is the long retention time necessary to achieve complete settling, especially if the specific gravity of the suspended matter is close to that of water. Some materials cannot be practically removed by simple settling alone.

Settling performed in a clarifier is effective in removing slow-settling suspended matter in a shorter time and in less space than a simple settling system. Also, effluent quality is often better from a clarifier. The cost of installing and maintaining a clarifier, however, is substantially greater than the costs associated with simple settling.

Inclined plate, slant tube, and lamella settlers have even higher removal efficiencies than conventional clarifiers, and greater capacities per unit area are possible. Installed costs for these advanced clarification systems are claimed to be one half the cost of conventional systems of similar capacity.

Operational Factors. Reliability: Settling can be a highly reliable technology for removing suspended solids. Sufficient retention time and regular sludge removal are important factors affecting the reliability of all settling systems. Proper control of pH adjustment, chemical precipitation, and coagulant or flocculant addition are additional factors affecting settling efficiencies in systems (frequently clarifiers) where these methods are used.

Those advanced settlers using slanted tubes, inclined plates, or a lamellar network may require pre-screening of the waste in order to eliminate any fibrous materials which could potentially clog the system. Some installations are especially vulnerable to shock loadings, as by storm water runoff, but proper system design will prevent this.

Maintainability: When clarifiers or other advanced settling devices are used, the associated system utilized for chemical pretreatment and sludge dragout must be maintained on a regular basis. Routine maintenance of mechanical parts is also necessary. Lagoons require little maintenance other than periodic sludge removal.

Demonstration Status

Settling represents the typical method of solids removal and is employed extensively in industrial wastewater treatment. The advanced clarifiers are just beginning to appear in significant numbers in commercial applications. Twenty three canmaking plants practice settling; all of these use settling following caustic or lime precipitation.

7. Skimming

Pollutants with a specific gravity less than water will often float unassisted to the surface of the wastewater. Skimming removes these floating wastes. Skimming normally takes place in a tank designed to allow the floating debris to rise and remain on the surface, while the liquid flows to an outlet located below the floating layer. Skimming devices are therefore suited to the removal of nonemulsified oils from raw waste streams. Common skimming mechanisms include the rotating drum type, which picks up oil from the surface of the water as it rotates. A doctor blade scrapes oil from the drum and collects it in a trough for disposal or reuse. The water portion is allowed to flow under the rotating drum. Occasionally, an underflow baffle is installed after the drum; this has the advantage of retaining any floating oil which escapes the drum skimmer. The belt type skimmer is pulled vertically through the water, collecting oil which is scraped off from the surface and collected in a drum. Gravity separators, such as the API type, utilize overflow and underflow baffles to skim a floating oil layer from the surface of the wastewater. An overflow-underflow baffle allows a small amount of wastewater (the oil portion) to flow over into a trough for disposition or reuse while the majority of the water flows underneath the baffle. This is followed by an overflow baffle, which is set at a height relative to the first baffle such that only the oil bearing portion will flow over the first baffle during normal plant operation. A diffusion device, such as a vertical slot baffle, aids in creating a uniform flow through the system and increasing oil removal efficiency.

Application and Performance. Lubricants cleaned from most seamless cans during the canwashing process are the principal source of oil. Skimming is applicable to any wastewater stream containing pollutants which float to the surface. It is commonly used to remove free oil and grease. Skimming is often used in conjunction with air flotation or clarification in order to increase its effectiveness.

The removal efficiency of a skimmer is partly a function of the retention time of the water in the tank. Larger, more buoyant particles require less retention time than smaller particles. Thus, the efficiency also depends on the composition of the waste stream. The retention time required to allow phase separation and subsequent skimming varies from 1 to 15 minutes, depending on the wastewater characteristics.

API or other gravity-type separators tend to be more suitable for use where the amount of surface oil flowing through the system is consistently significant. Drum and belt type skimmers are applicable to wastewater streams which evidence smaller amounts of floating oil and where surges of floating oil are not a problem. Using an API separator system in conjunction with a drum type skimmer would be a very effective method of removing floating contaminants from non-emulsified oily waste streams. Sampling data illustrate the capabilities of the technology with both extremely high and moderate oil influent levels.

These data, displayed in Table VII-11 (page 222), are intended to be illustrative of the very high level of oil and grease removals attainable in a simple two stage oil removal system. Based on the performance of installations in a variety of manufacturing plants and permit requirements that are constantly achieved, it is determined that effluent oil levels may be reliably reduced below 10 mg/l with moderate influent concentrations. Very high influent concentrations of oil such as the 22 percent shown in the Table for plant 06058 may require two step treatment in order to achieve 10 mg/l in the treated effluent.

Skimming which removes oil may also be used to remove base levels of organics. Plant sampling data show that many organic compounds tend to be removed in standard wastewater treatment equipment. Oil separation not only removes oil but also organics that are more soluble in oil than in water. Clarification removes organic solids directly and probably removes dissolved organics by adsorption on inorganic solids.

The source of these organic pollutants is not always known with certainty, although in metal forming operations they seem to derive mainly from various process lubricants. They are also sometimes present in the plant water supply, as additives to proprietary formulations of cleaners, or due to leaching from plastic lines and other materials.

High molecular weight organics in particular are much more soluble in organic solvents than in water. Thus they are much more concentrated in the oil phase that is skimmed than in the wastewater. The ratio of solubilities of a compound in oil and water phases is called the partition coefficient. Table VII-12 (page 223) lists the logarithm of the partition coefficients in octanol and water for selected polynuclear aromatic hydrocarbon (PAH) compounds and for other organic compounds found in canmaking wastewaters.

A review of toxic organic compounds found in metal forming wastewater streams indicates that removal of these compounds often occurs as a result of oil removal or clarification processes. When all available organics analyses from aluminum forming, copper forming, and coil coating are considered, removal of organic compounds appears to be marginal by waste treatment technologies other than oil removal or clarification. Organics removal as a result of oil removal becomes especially apparent when raw waste concentrations of organics are above 0.05 mg/l, but are also demonstrated when raw waste concentrations are less than this value. The API oil-water separation system performed notably in this regard, as shown in Table VII-13 (page 224). When these factors are taken into account, analysis data indicate that most clarification and oil removal treatment systems remove significant amounts of the organic compounds present in the raw wastewater.

Data from five plant days demonstrate removal of organics by the combined oil skimming and settling operations performed on coil coating wastewaters. Days were chosen where treatment system influent and effluent analyses provided paired data points for oil and grease and the organics present. All organics found at quantifiable levels on those days were included. Further, only those days were chosen where oil and grease concentrations in raw wastewater exceeded 10 mg/l and where there was reduction in oil and grease going through the treatment system. All plant sampling days which met the above criteria are included below. The conclusion is that when oil and grease is removed, toxic organics are removed, also.

	Percent Removal	
Plant-Day	Oil & Grease	Organics
1054-3	95.9	98.2
13029-2	98.3	78.0
13029-3	95.1	77.0
38053-1	96.8	81.3
38053-2	98.5	86.3
Mean	96.9	84.2

For aluminum forming wastewaters, effective oil removal technology (such as oil skimming or emulsion breaking) is capable of removing approximately 97 percent of the total toxic organics (TTO) from the raw waste. As shown in Table VII-29 (page 235), the achievable TTO concentration is approximately 0.690 mg/l. The influent and effluent concentrations presented for each pollutant were taken from the aluminum forming category for several plants with effective oil removal technologies in place. In calculating the concentrations, if only one day's sampling datum was available, that value was used; if two day's sampling data were available, the higher of the values was used; and, if three day's sampling data were available, the mean or the median value was used, whichever was higher. The 0.690 mg/l value is an appropriate basis for effluent limitations, since the highest values were used in the calculation.

The estimated level of oil and grease in raw wastewater at BAT flow levels for the categories discussed above is:

Source		Untreated Oil Concentration
Aluminum Forming (rolling with emulsions)	-	17,752 mg/l
Coil Coating (Steel subcategory)	-	801.5 mg/l
(Canmaking Subcategory)	-	19,838 mg/l

Advantages and Limitations. Skimming as a pretreatment is effective in removing naturally floating waste material. It also improves the performance of subsequent downstream treatments. Many pollutants, particularly dispersed or emulsified oil, will not float "naturally" but require additional treatments. Therefore, skimming alone may not remove all the pollutants capable of being removed by air flotation or other more sophisticated technologies.

Operational Factors. Reliability: Because of its simplicity, skimming is a very reliable technique.

Maintainability: The skimming mechanism requires periodic lubrication, adjustment, and replacement of worn parts.

Solid Waste Aspects: The collected layer of debris must be disposed of by contractor removal, landfill, or incineration. Because relatively large quantities of water are present in the collected wastes, incineration is not always a viable disposal method.

Demonstration Status. Skimming is a common operation utilized extensively by industrial waste treatment systems. Oil removal equipment for skimming as a separate process or in conjunction with chemical emulsion breaking, or dissolved air flotation (discussed below) is in place at 21 canmaking plants.

MAJOR TECHNOLOGY EFFECTIVENESS

The performance of individual treatment technologies was presented above. Performance of operating systems is discussed here. Two different systems are considered: L&S (hydroxide precipitation and sedimentation or lime and settle) and LS&F (hydroxide precipitation, sedimentation and filtration or lime, settle, and filter). Subsequently, an analysis of effectiveness of such systems is made to develop one-day maximum, and ten-day and thirty-day average concentration levels to be used in regulating pollutants. Evaluation of the L&S and the LS&F systems is carried out on the assumption that chemical reduction of chromium, cyanide precipitation, and oil removal are installed and operating properly where appropriate.

L&S Performance -- Combined Metals Data Base

A data base known as the "combined metals data base" (CMDB) was used to determine treatment effectiveness of lime and settle treatment for certain pollutants. The CMDB was developed over several years and has been used in a number of regulations. During the development of coil coating and other categorical effluent limitations and standards, chemical analysis data were collected of raw wastewater (treatment influent) and treated wastewater (treatment effluent) from 55 plants (126 data days) sampled by EPA (or its contractor) using EPA sampling and chemical analysis protocols. These data are the initial data base for determining the effectiveness of L&S technology in treating nine pollutants. Each of the plants in the initial data base belongs to at least one of the following industry categories: aluminum forming, battery manufacturing, coil coating (including canmaking), copper forming, electroplating and porcelain enameling. All of the plants employ pH adjustment and hydroxide precipitation using lime or caustic, followed by Stokes' law settling (tank, lagoon or clarifier) for solids removal. An analysis of this data was presented in the development documents for the proposed regulations for coil coating and porcelain enameling (January 1981). Prior to analyzing the data, some values were deleted from the data base. These deletions were made to ensure that the data reflect properly operated treatment systems. The following criteria were used in making these deletions:

- Plants where malfunctioning processes or treatment systems at the time of sampling were identified.
- Data days where pH was less than 7.0 for extended periods of time or TSS was greater than 50 mg/l (these are prima facie indications of poor operation).

In response to the coil coating and porcelain enameling proposals, some commenters claimed that it was inappropriate to use data from some categories for regulation of other categories. In response to these comments, the Agency reanalyzed the data. An analysis of variance was applied to the data for the 126 days of sampling to test the hypothesis of homogeneous plant mean raw and treated effluent levels across categories by pollutant. This analysis is described in the report "A Statistical Analysis of the Combined Metals Industries Effluent Data" which is in the administrative record supporting this rulemaking. The main conclusion drawn from the analysis of variance is that, with the exception of electroplating, the categories included in the data base are generally homogeneous with regard to mean pollutant concentrations in both raw and treated effluent. That is, when data from electroplating facilities are included in the analysis, the hypothesis of homogeneity across categories is rejected. When the electroplating data are removed from the analysis the conclusion changes substantially and the hypothesis of homogeneity across categories is not rejected. On the basis of this analysis, the electroplating data were removed from the data base used to determine limitations for the final coil coating and porcelain enameling regulations and proposed regulations for copper forming, aluminum forming, battery manufacturing, nonferrous metals (Phase I) and canmaking.

The statistical analysis provides support for the technical engineering judgment that electroplating wastewaters are sufficiently different from the wastewaters of other industrial categories in the data base to warrant removal of electroplating data from the data base used to determine treatment effectiveness.

For the purpose of determining treatment effectiveness, additional data were deleted from the data base. These deletions were made, almost exclusively, in cases where effluent data points were associated with low influent values. This was done in two steps. First, effluent values measured on the same day as influent values that were less than or equal to 0.1 mg/l were deleted. Second, the remaining data were screened for cases in which all influent values at a plant were low although slightly above the 0.1 mg/l value. These data were deleted not as individual data points but as plant clusters of data that were consistently low and thus not relevent to assessing treatment. A few data points were also deleted where malfunctions not previously identified were recognized. The data basic to the CMDB are displayed graphically in Figures VII-4 to 12 (Pages 240 - 248).

After all deletions, 148 data points from 19 plants remained. These data were used to determine the concentration basis of limitations derived from the CMDB used for the proposed canmaking regulations.

The CMDB was used as the basis for limitations in canmaking because the model treatment technology for canmaking, lime and settle, was the same as for the categories represented in the CMDB. The selection of lime and settle was based on the judgment that the process steps and wastewater characteristics in canmaking were similar to other categories that process metals for which lime and settle is an appropriate and demonstrated technology.

The basic approach in analyzing the combined metals data was to establish statistical homogeneity of the categories with respect to observed mean pollutant concentrations in both raw and treated effluent wastewater. For the proposed canmaking regulation, the available raw wastewater data from canmaking were analyzed along with the CMDB raw wastewater data. In the analysis, canmaking was treated as an additional category in the CMDB and the same statistical procedures used to assess homogeneity of the combined metals categories were performed.

The results indicated substantial homogeneity among untreated wastewater from canmaking and the combined metals categories. Homogeneity is the absence of statistically discernable differences among the categories while heterogeneity is the opposite, i.e., the presence of statistically discernable differences. The homogeneity found among the canmaking raw waste data and the combined metals raw waste data supported the hypothesis of similar raw waste characteristics and suggests that lime and settle treatment will reduce the concentrations of toxic metal pollutants in canmaking to levels comparable to those achievable by lime and settle treatment of wastewater from the other categories.

The CMDB was reviewed following its use in a number of proposed regulations (including canmaking). Comments pointed out a few errors in the data and the Agency's review identified a few transcription errors and some data points that were appropriate for inclusion in the data that had not been used previously because of errors in data record identification numbers. Documents in the record of this rulemaking identify all the changes, the reasons for the changes, and the effect of these changes on the data base. Other comments on the CMDB asserted that the data base was too small and that the statistical methods used were overly complex. Responses to specific comments are provided in a document included in the canmaking rulemaking. The Agency believes that the data base is adequate to determine effluent concentrations achievable with lime and settle treatment. The statistical methods employed in the analysis are well known and appropriate statistical references are provided in the documents in the record that describe the analysis.

The revised data base was re-examined for homogeneity. The earlier conclusions were unchanged. The categories show good overall homogeneity with respect to concentrations of the nine pollutants in both raw and treated wastewaters with the exception of electroplating.

The same procedures used in developing proposed limitations from the combined metals data base were then used on the revised data base. That is, certain effluent data associated with low influent values were deleted, and then the remaining data were fit to a lognormal distribution to determine limitations values. The deletion of data was done in two steps. First, effluent values measured on the same day as influent values that were less than or equal to 0.1 mg/l were deleted. Second, the remaining data were screened for cases in which all influent values at a plant were low although slightly above the 0.1 mg/l value. These data were deleted not as individual data points but as plant clusters of data that were consistently low and thus not relevant to assessing treatment.

The revised combined metals data base used for this final regulation consists of 162 data points from 18 plants in the same industrial categories used at proposal. The changes that were made since proposal resulted in slight upward revisions of the concentration bases for the limitations and standards for zinc and nickel. The limitations for iron decrease slightly. The other limitations were unchanged. A comparison of Table VII-21 in the final development document with Table VII-21 in the proposal development document will show the exact magnitude of the changes.

Following the proposal of the canmaking regulation, the industry submitted raw and treated effluent data on chromium, zinc and TSS from a number of canmaking plants. Some of these industry sampled plants had appropriate lime and settle treatment. All of the raw data from these plants and the suitable effluent data were analyzed for homogeneity with the CMDB data and the aluminum canmaking raw data available at proposal. The approach was the same used at proposal in the analysis of the raw canmaking data. That is, the canmaking data were treated as another category in the CMDB and the same analysis of variance procedures were repeated. The results show a similar pattern of homogeneity among the canmaking data (including the industry supplied data) and the other CMDB categories. This analysis is described in detail in the record of canmaking rulemaking.

Comments on the canmaking proposal also asserted that dissolved air flotation (DAF) was as effective as lime and settle technology in treating canmaking wastewater. The Agency analyzed data collected and submitted by the industry from plants with either DAF or lime and settle treatment in order to address this issue. Raw and treated effluent data on chromium, zinc, aluminum and TSS were available. The raw concentrations at the DAF plants were not significantly different from the lime and settle plants. However, the treated effluent values for aluminum and TSS were significantly lower in effluent at the lime and settle plants. The effluent zinc mean was lower for the lime and settle plants although not significantly lower and the chromium means were approximately equal. These data support the Agency's contention that DAF is not as effective as lime and settle for these pollutants. In fact, the evidence is rather strong since the influent concentrations were substantial only for aluminum and TSS. For chromium and zinc the influent concentrations at both the DAF and lime and settle plants were low and thus the removals achieved are difficult to assess. The details of the analysis of DAF versus lime and settle are in the canmaking record.

Another issue raised in the canmaking comments was the question of whether caustic was as effective as lime in treating fluoride in canmaking wastewater. Commenters asserted that caustic and lime were equally as effective. The Agency had fluoride data from 3 plants that use lime and 8 plants that use caustic. Statistical analysis of these data show the lime group achieved significantly lower fluoride concentrations. In addition, the data show the caustic group exceeded the concentration basis for the fluoride limitation in over half the samples while the lime group shows no exceedances of the limitation.

Aluminum was not one of the pollutants included in the CMDB. As described in Section IX, limitations for aluminum that apply to canmaking direct dischargers were developed from aluminum effluent data collected by EPA at 3 aluminum forming plants and one aluminum coil coating plant. The use of these aluminum data in canmaking was supported by comparison with aluminum data collected by industry at canmaking plants with appropriate lime and settle treatment. Comparison of the industry aluminum effluent data (3 plants, 8 observations) with the EPA data (4 plants, 11 observations) showed no significant difference between the two groups. Also, comparison of influent aluminum data collected by industry and EPA at canmaking plants and the influent aluminum data corresponding to the effluent data used to determine the aluminum limitations showed no significant difference among the two groups. The details of this comparison are also described in the canmaking record.

One-day Effluent Values

The same procedures used to determine the concentration basis of the limitations for lime and settle treatment from the CMDB at proposal were used in the revised CMDB for the final limitations. The basic assumption underlying the determination of treatment effectiveness is that the data for a particular pollutant are lognormally distributed by plant. The lognormal has been found to provide a satisfactory fit to plant effluent data in a number of effluent guidelines categories and there was no evidence that the lognormal was not suitable in the case of the CMDB. Thus, we assumed measurements of each pollutant from a particular plant, denoted by X, were assumed followed a lognormal distribution with log mean μ and log variance σ^2. The mean, variance and 99th percentile of X are then:

$$\text{mean of } X = E(X) = \exp(\mu + \sigma^2/2)$$

$$\text{variance of } X = V(X) = \exp(2\mu + \sigma^2)\,[\exp(\sigma^2) - 1]$$

$$\text{99th percentile} = X_{.99} = \exp(\mu + 2.33\,\sigma)$$

where exp is e, the base of the natural logarithm. The term lognormal is used because the logarithm of X has a normal distribution with mean μ and variance σ^2. Using the basic assumption of lognormality the actual treatment effectiveness was determined using a lognormal distribution that, in a sense, approximates the distribution of an average of the plants in the data base, i.e., an "average plant" distribution. The notion of an "average plant" distribution is not a strict statistical concept but is used here to determine limits that would represent the performance capability of an average of the plants in the data base.

This "average plant" distribution for a particular pollutant was developed as follows: the log mean was determined by taking the average of all the observations for the pollutant across plants. The log variance was determined by the pooled within plant variance. This is the weighted average of the plant variances. Thus, the log mean represents the average of all the data for the pollutant and the log variance represents the average of the plant log variances or average plant variability for the pollutant.

The one day effluent values were determined as follows:

Let X_{ij} = the jth observation on a particular pollutant at plant i where

$i = 1, \ldots, I$
$j = 1, \ldots, J_i$
I = total number of plants
J_i = number of observations at plant i.

Then $y_{ij} = \ln X_{ij}$

where ln means the natural logarithm.

Then $\bar{y}$ = log mean over all plants

$$= \sum_{i=1}^{I} \sum_{j=1}^{J_i} y_{ij}/n,$$

where n = total number of observations

$$= \sum_{i=1}^{I} J_i$$

and $V(y)$ = pooled log variance

$$= \frac{\sum_{i=1}^{I}(J_i - 1)\, S_i^2}{\sum_{i=1}^{I}(J_i - 1)}$$

where Si^2 = log variance at plant i

$$= \sum_{j=1}^{J_i}(y_{ij} - \overline{y}_i)^2/(J_i - 1)$$

$\overline{y}_i$ = log mean at plant i.

Thus, $\overline{y}$ and $V(y)$ are the log mean and log variance, respectively, of the lognormal distribution used to determine the treatment effectiveness. The estimated mean and 99th percentile of this distribution form the basis for the long term average and daily maximum effluent limitations, respectively. The estimates are

$$\text{mean} = \hat{E}(X) = \exp(\overline{y})\ \Psi n\ (0.5\ V(y))$$

$$\text{99th percentile} = \hat{X}_{.99} = \exp\ [\overline{y} + 2.33\sqrt{V(y)}\ ]$$

where Ψ (.) is a Bessel function and exp is e, the base of the natural logarithms (See Aitchison, J. and J.A.C. Brown, The Lognormal Distribution, Cambridge University Press, 1963). In cases where zeros were present in the data, a generalized form of the lognormal, known as the delta distribution was used (See Aitchison and Brown, op. cit., Chapter 9).

For certain pollutants, this approach was modified slightly to ensure that well operated lime and settle plants in all CMDB categories would achieve the pollutant concentration values calculated from the CMDB. For instance, after excluding the electroplating data and other data that did not reflect pollutant removal or proper treatment, the effluent copper data from the copper forming plants were statistically significantly greater than the copper data from the other plants. This indicated that copper forming plants might have difficulty achieving an effluent concentration value calculated from copper data from all CMDB categories. Thus, copper effluent values shown in Table VII-14 (page 224) are based only on the copper effluent data from the copper forming plants. That is, the log mean for copper is the mean of the logs of all copper values from the copper forming plants only and the log variance is the pooled log variance of the copper forming plant data only. In the case of cadmium, after excluding the electroplating data and data that did not reflect removal or proper treatment, there were insufficient data to estimate the log variance for cadmium. The variance used to determine the values shown in Table VII-14 for cadmium was estimated by pooling the within plant variances for all the other metals. Thus, the cadmium variability is the average of the plant variability averaged over all the other metals. The log mean for cadmium is the mean of the logs of the cadmium observations only. A complete discussion of the data and calculations for all the metals is contained in the administrative record for this rulemaking.

Average Effluent Values

Average effluent values that form the basis for the monthly limitations were developed in a manner consistent with the method used to develop one-day treatment effectiveness in that the lognormal distribution used for the one-day effluent values was also used as the basis for the average values. That is, we assume a number of consecutive measurements are drawn from the distribution of daily measurements. The average of ten measurements taken during a month was used as the basis for the monthly average limitations. The approach used for the 10 measurements values was employed previously in regulations for other categories and was proposed for the canmaking subcategory. That is, the distribution of the average of 10 samples from a lognormal was approximated by another lognormal distribution. Although the approximation is not precise theoretically, there is empirical evidence based on effluent data from a number of categories that the lognormal is an adequate approximation for the distribution of small samples. In the course of previous work the approximation was verified in a computer simulation study (see "Development Document for Existing Sources Pretreatment Standards for the Electroplating Point Source Category", EPA 440/1-79/003, U.S. Environmental Protection Agency, Washington, D.C., August 1979). We also note that the average values were developed assuming independence of the observations although no particular sampling scheme was assumed.

Ten-Sample Average

The formulas for the 10-sample limitations were derived on the basis of simple relationships between the mean and variance of the distributions of the daily pollutant measurements and the average of 10 measurements. We assume the daily concentration measurements for a particular pollutant, denoted by X, follow a lognormal distribution with log mean and log variance denoted by μ and σ^2, respectivey. Let $\overline{X}_{10}$ denote the mean of 10 consecutive measurements. The following relationships then hold assuming the daily measurements are independent:

$$\text{mean of } \overline{X}_{10} = E(\overline{X}_{10}) = E(X)$$

$$\text{variance of } \overline{X}_{10} = V(\overline{X}_{10}) = V(X) \div 10.$$

Where $E(X)$ and $V(X)$ are the mean and variance of X, respectively, defined above. We then assume that $\overline{X}_{10}$ follows a lognormal distribution with log mean μ_{10} and log standard deviation σ^2. The mean and variance of $\overline{X}_{10}$ are then

$$E(\overline{X}_{10}) = \exp(\mu_{10} + 0.5\, \sigma^2_{10})$$
$$V(\overline{X}_{10}) = \exp(2\, \mu_{10} + \sigma^2_{10})\, [\exp(\sigma^2_{10}) - 1]$$

Now, μ_{10} and σ^2_{10} can be derived in terms of μ and σ^2 as

$$\mu_{10} = \mu + \sigma^2/2 - 0.5 \ln [1 + (\exp(\sigma^2 - 1)/N]$$
$$\sigma^2_{10} = \ln [1 + (\exp(\sigma^2) - 1)/N]$$

Therefore, μ_{10} and σ^2_{10} can be estimated using the above relationships and the estimates of μ and σ^2 obtained for the underlying lognormal distribution. The 10 sample limitation value was determined by the estimate of the approximate 99th percentile of the distribution of the 10 sample average given by

$$\widehat{X_{10}}\,(.99) = \exp(\hat{\mu}_{10} + 2.33\, \hat{\sigma}_{10}).$$

where $\hat{\mu}_{10}$ and $\hat{\sigma}_{10}$ are the estimates of μ_{10} and σ_{10}, respectively.

Thirty Sample Average

Monthly average values based on the average of 30 daily measurements were also calculated. These are included because monthly limitations based on 30 samples have been used in the past and for comparison with the 10 sample values. The average values based on 30 measurements are determined on the basis of a statistical result known as the Central Limit Theorem. This Theorem states that, under general and nonrestrictive assumptions, the distribution of a sum of a number of random variables, say n, is approximated by the normal distribution. The approximation improves as the number of variables, n, increases. The Theorem is quite general in that no particular distributional form is assumed for the distribution of the individual variables. In most applications (as in approximating the distribution of 30-day averages) the Theorem is used to approximate the distribution of the average of n observations of a random variable. The result makes it possible to compute approximate probability statements about the average in a wide range of cases. For instance, it is possible to compute a value below which a specified percentage (e.g., 99 percent) of the averages of n observations are likely to fall. Most textbooks state that 25 or 30 observations are sufficient for the approximation to be valid. In applying the Theorem to the distribution of the 30 day average effluent values, we approximate the distribution of the average of 30 observations drawn from the distribution of daily measurements and use the estimated 99th percentile of this distribution.

Thirty Sample Average Calculation

The formulas for the 30 sample average were based on an application of the Central Limit Theorem. According to the Theorem, the average of 30 observations drawn from the distribution of daily measurements, denoted by $\overline{X}_{30}$, is approximately normally distributed. The mean and variance of $\overline{X}_{30}$ are:

$$\text{mean of } \overline{X}_{30} = E(\overline{X}_{30}) = E(X)$$
$$\text{variance of } \overline{X}_{30} = V(\overline{X}_{30}) = V(X) \div 30.$$

The 30 sample average value was determined by the estimate of the approximate 99th percentile of the distribution of the 30 sample average given by

$$\hat{\overline{X}}_{30}(.99) = \hat{E}(X) + 2.33 \sqrt{\hat{V}(X) \div 30}$$

where

$$\hat{E}(X) = \exp(\overline{y})\ \psi_n(0.5V(y))$$

$$\text{and } \hat{V}(X) = \exp(2\overline{y})[\ \psi_n(2V(y)) - \psi_n\left(\left(\frac{n-2}{n-1}\right)V(y)\right)].$$

The formulas for $\hat{E}(X)$ and $\hat{V}(X)$ are estimates of $E(X)$ and $V(X)$ respectively given in Aitchison, J. and J.A.C. Brown, The Lognormal Distribution, Cambridge University Press, 1963, page 45.

Application

In response to the proposed coil coating and porcelain enameling regulations, the Agency received comments pointing out that permits usually required less than 30 samples to be taken during a month while the monthly average used as the basis for permits and pretreatment requirements usually is based on the average of 30 samples.

In applying the treatment effectiveness values to regulations we have considered the comments, examined the sampling frequency required by many permits and considered the change in values of averages depending on the number of consecutive sampling days in the averages. The most common frequency of sampling required in permits is about ten samples per month or slightly greater than twice weekly. The 99th percentiles of the distribution of averages of ten consecutive sampling days are not substantially different from the 99th percentile of the distribution's 30-day average. (Compared to the one-day maximum, the ten-day average is about 80 percent of the difference between one-and 30-day values). Hence the ten-day average provides a reasonable basis for a monthly average limitation and is typical of the sampling frequency required by existing permits.

The monthly average limitation is to be achieved in all permits and pretreatment standards regardless of the number of samples required to be analyzed and averaged by the permit or the pretreatment authority.

CANMAKING DATA - To determine the applicability of the combined metals data base to canmaking an analysis was made using the canmaking data shown in Table V-8 (page 62). For homogeniety analysis, canmaking was treated as if it were an additional category in the combined metals data base and the same statistical procedures used to assess homogeneity of the combined metals data were performed. The results indicate substantial homogeneity among untreated wastewater data from canmaking and the combined metals categories except for zinc which was significantly lower than CMDB. The results of overall homogeneity were the same with and without the canmaking data. These results support the hypothesis of similar raw waste characteristics among canmaking and the combined metals categories and suggest that lime and settle treatment would reduce concentrations of the CMDB pollutants in canmaking to levels comparable to those achievable by lime and settle in the CMDB categories. Additionally, the concentrations of aluminum, fluoride and phosphorus found in canmaking raw wastewaters are comparable to or lower than values for these pollutants found used as a basis for establishing treatment effectiveness suggesting that L&S technology would remove these pollutants to the levels shown in Table VII-21. Similarily, the lime, settle, and filter discussion which follows is applicable to canmaking wastewater the same as any other wastewater in the combined metals data base. The analysis of the canmaking wastewater data and of the combined metals data base is detailed in the administrative record of this rulemaking.

Additional Pollutants

Ten additional pollutant parameters were evaluated to determine the performance of lime and settle treatment systems in removing them from industrial wastewater. Performance data for these parameters is not a part of the CMDB so other data available to the Agency from other categories has been used to determine the long term average performance of lime and settle technology for each pollutant. These data indicate that the concentrations shown in Table VII-15 (page 225) are reliably attainable with hydroxide precipitation and settling. Treatment effectiveness values were calculated by multiplying the mean performance from Table VII-15 (page 225) by the appropriate variability factor. (The variability factor is the ratio of the value of concern to the mean). The pooled variability factors are: one-day maximum - 4.100; ten-day average - 1.821; and 30-day average - 1.618 these one-, ten- and thirty-day values are tabulated in Table VII-21 (page 230).

In establishing which data were suitable for use in Table VII-14 two factors were heavily weighed; (1) the nature of the wastewater; and (2) the range of pollutants or pollutant matrix in the raw wastewater. These data have been selected from processes that generate dissolved metals in the wastewater and which are generally free from complexing agents. The pollutant matrix was evaluated by comparing the concentrations of pollutants found in the raw wastewaters with the range of pollutants in the raw wastewaters of the combined metals data set. These data are displayed in Tables VII-16 (page 225) and VII-17 (page 226) and indicate that there is sufficient similarity in the raw wastes to logically assume transferability of the treated pollutant concentrations to the combined metals data base. Canmaking wastewaters also were compared to the wastewaters from plants in categories from which treatment effectiveness values were calculated. The available data on these added pollutants do not allow homogeneity analysis as was performed on the combined metals data base. The data source for each added pollutant is discussed separately.

Antimony (Sb) - The achievable performance for antimony is based on data from a battery and secondary lead plant. Both EPA sampling data and recent permit data (1978-1982) confirm the achievability of 0.7 mg/l in the battery manufacturing wastewater matrix included in the combined data set.

Arsenic (As) - The achievable performance of 0.5 mg/l for arsenic is based on permit data from two nonferrous metals manufacturing plants. The untreated wastewater matrix shown in Table VII-17 (page 226) is comparable with the combined metals data base matrix.

Beryllium (Be) - The treatability of beryllium is transferred from the nonferrous metals manufacturing industry. The 0.3 mg/l performance is achieved at a beryllium plant with the comparable untreated wastewater matrix shown in Table VII-17.

Mercury (Hg) - The 0.06 mg/l treatability of mercury is based on data from four battery plants. The untreated wastewater matrix at these plants was considered in the combined metals data base.

Selenium (Se) - The 0.30 mg/l treatability of selenium is based on recent permit data from one of the nonferrous metals manufacturing plants also used for antimony performance. The untreated wastewater matrix for this plant is shown in Table VII-17.

Silver - The treatability of silver is based on a 0.1 mg/l treatability estimate from the inorganic chemicals industry. Additional data supporting a treatability as stringent or more stringent than 0.1 mg/l is also available from seven nonferrous metals manufacturing plants. The untreated wastewater matrix for these plants is comparable and summarized in Table VII-17.

Thallium (Tl) - The 0.50 mg/l treatability for thallium is transferred from the inorganic chemicals industry. Although no untreated wastewater data are available to verify comparability with the combined metals data set plants, no other sources of data for thallium treatability could be identified.

Aluminum (Al) - The 2.24 mg/l treatability of aluminum is based on the mean performance of three aluminum forming plants and one coil coating plant. These plants are from categories included in the combined metals data set, assuring untreated wastewater matrix comparability.

Cobalt (Co) - The 0.05 mg/l treatability is based on nearly complete removal of cobalt at a porcelain enameling plant with a mean untreated wastewater cobalt concentration of 4.31 mg/l. In this case, the analytical detection using aspiration techniques for this pollutant is used as the basis of the treatability. Porcelain enameling was considered in the combined metals data base, assuring untreated wastewater matrix comparability.

Fluoride (F) - The 14.5 mg/l treatability of fluoride is based on the mean performance (216 samples) of an electronics manufacturing plant. The untreated wastewater matrix for this plant shown in Table VII-17 is comparable to the combined metals data set. The fluoride level in the electronics wastewater (760 mg/l) is significantly greater than the fluoride level in raw canmaking wastewater (16.7 mg/l - see Table X-1) leading to the conclusion that the canmaking wastewater should be no more difficult to treat for fluoride removal than the electronics wastewater. The fluoride level in the CMDB - electroplating data ranges from 1.29 to 70.0 mg/l while the fluoride level in the canmaking wastewater was lower ranging from <1.0 to 16.5 mg/l and leading to the conclusion that the canmaking wastewater should be no more difficult to treat to remove fluoride than electroplating wastewater.

Phosphorus (P) - The 4.08 mg/l treatability of phosphorus is based on the mean of 44 samples including 19 samples from the Combined Metals Data Base and 25 samples from the electroplating data base. Inclusion of electroplating data with the combined metals data was considered appropriate, since the removal mechanism for phosphorus is a precipitation reaction with calcium rather than hydroxide.

LS&F Performance

Tables VII-18 and VII-19 (pages 227 and 228) show long term data from two plants which have well operated precipitation-settling treatment followed by filtration. The wastewaters from both plants contain pollutants from metals processing and finishing operations (multi-category). Both plants reduce hexavalent chromium before neutralizing and precipitating metals with lime. A clarifier is used to remove much of the solids load and a filter is used to "polish" or complete removal of suspended solids. Plant A uses a pressure filter, while Plant B uses a rapid sand filter.

Raw wastewater data was collected only occasionally at each facility and the raw wastewater data is presented as an indication of the nature of the wastewater treated. Data from plant A was received as a statistical summary and is presented as received. Raw laboratory data was collected at plant B and reviewed for spurious points and discrepancies. The method of treating the data base is discussed below under lime, settle, and filter treatment effectiveness.

Table VII-20 (page 229) shows long-term data for zinc and cadmium removal at Plant C, a primary zinc smelter, which operates a LS&F system. This data represents about 4 months (103 data days) taken immediately before the smelter was closed. It has been arranged similarily to Plants A and B for comparison and use.

These data are presented to demonstrate the performance of precipitation-settling-filtration (LS&F) technology under actual operating conditions and over a long period of time.

It should be noted that the iron content of the raw wastewater of plants A and B is high while that for Plant C is low. This results, for plants A and B, in co-precipitation of toxic metals with iron. Precipitation using high-calcium lime for pH control yields the results shown above. Plant operating personnel indicate that this chemical treatment combination (sometimes with polymer assisted coagulation) generally produces better and more consistent metals removal than other combinations of sacrificial metal ions and alkalis.

The LS&F performance data presented here are based on systems that provide polishing filtration after effective L&S treatment. We have previously shown that L&S treatment is equally applicable to wastewaters from the five categories because of the homogeneity of its raw and treated wastewaters, and other factors. Because of the similarity of the wastewaters after L&S treatment, the Agency believes these wastewaters are equally amenable to treatment using polishing filters added to the L&S treatment system. The Agency concludes that LS&F data based on porcelain enameling and nonferrous smelting and refining is directly applicable to the aluminum forming, copper forming, battery manufacturing, coil coating, and metal molding and casting categories, and the canmaking subcategory as well as it is to porcelain enameling and nonferrous melting and refining.

Analysis of Treatment System Effectiveness

Data are presented in Table VII-14 showing the mean, one-day, 10-day, and 30-day values for nine pollutants examined in the L&S combined metals data base. The pooled variability factor for seven metal pollutants (excluding cadmium because of the small number of data points) was determined and is used to estimate one-day, 10-day and 30-day values. (The variability factor is the ratio of the value of concern to the mean: the pooled variability factors are: one-day maximum - 4.100; ten-day average - 1.821; and 30-day average - 1.618.) For values not calculated from the common data base as previously discussed, the mean value for pollutants shown in Table VII-15 were multiplied by the variability factors to derive the value to obtain the one-, ten- and 30-day values. These are tabulated in Table VII-21.

LS&F technology data are presented in Tables VII-18 and VII-19. These data represent two operating plants (A and B) in which the technology has been installed and operated for some years. Plant A data was received as a statistical summary and is presented without change. Plant B data was received as raw laboratory analysis data. Discussions with plant personnel indicated that operating experiments and changes in materials and reagents and occasional operating errors had occurred during the data collection period. No specific information was available on those variables. To sort out high values probably caused by methodological factors from random statistical variability, or data noise, the plant B data were analyzed. For each of four pollutants (chromium, nickel, zinc, and iron), the mean and standard deviation (sigma) were calculated for the entire data set. A data day was removed from the complete data set when any individual pollutant concentration for that day exceeded the sum of the mean plus three sigma for that pollutant. Fifty-one data days (from a total of about 1300) were eliminated by this method.

Another approach was also used as a check on the above method of eliminating certain high values. The minimum values of raw wastewater concentrations from Plant B for the same four pollutants were compared to the total set of values for the corresponding pollutants. Any day on which the treated wastewater pollutant concentration exceeded the minimum value selected from raw wastewater concentrations for that pollutant was discarded. Forty-five days of data were eliminated by that procedure. Forty-three days of data in common were eliminated by either procedures. Since common engineering practice (mean plus 3 sigma) and logic (treated wastewater concentrations should be less than raw wastewater concentrations) seem to coincide, the data base with the 51 spurious data days eliminated is the basis for all further analysis. Range, mean plus standard deviation and mean plus two standard deviations are shown in Tables VII-18 and VII-19 for Cr, Cu, Ni, Zn and Fe.

The Plant B data was separated into 1979, 1978, and total data base (six years) segments. With the statistical analysis from Plant A for 1978 and 1979 this in effect created five data sets in which there is some overlap between the individual years and total data sets from Plant B. By comparing these five parts it is apparent that they are quite similar and all appear to be from the same family of numbers. The largest mean found among the five data sets for each pollutant was selected as the long term mean for LS&F technology and is used as the LS&F mean in Table VII-21.

Plant C data was used as a basis for cadmium removal performance and as a check on the zinc values derived from Plants A and B. The cadmium data is displayed in Table VII-20 (page 229) and is incorporated into Table VII-21 for LS&F. The zinc data was analyzed for compliance with the 1-day and 30-day values in Table VII-21; no zinc value of the 103 data points exceeded the 1-day zinc value of 1.02 mg/l. The 103 data points were separated into blocks of 30 points and averaged. Each of the 3 full 30-day averages was less than the Table VII-21 value of 0.31 mg/l. Additionally the Plant C raw wastewater pollutant concentrations (Table VII-20) are well within the range of raw wastewater concentrations of the combined metals data base (Table VII-16), further supporting the conclusion that Plant C wastewater data is compatible with similar data from Plants A and B.

Concentration values for regulatory use are displayed in Table VII-21. Mean one-day, ten-day and 30-day values for L&S for nine pollutants were taken from Table VII-14; the remaining L&S values were developed using the mean values in Table VII-15 and the mean variability factors discussed above.

LS&F mean values for Cd, Cr, Ni, Zn and Fe are derived from plants A, B, and C as discussed above. One-, ten- and thirty-day values are derived by applying the variability factor developed from the pooled data base for the specific pollutant to the mean for that pollutant. Other LS&F values are calculated using the long term average or mean and the appropriate variability factors. Mean values for LS&F for pollutants not already discussed are derived by reducing the L&S mean by one-third. The one-third reduction was established after examining the percent reduction in concentrations going from L&S to LS&F data for Cd, Cr, Ni, Zn, and Fe. The average reduction is 0.3338 or one third.

Copper levels achieved at Plants A and B may be lower than generally achievable because of the high iron content and low copper content of the raw wastewaters. Therefore, the mean concentration value achieved is not used; LS&F mean used is derived from the L&S technology.

L&S cyanide mean levels shown in Table VII-8 are ratioed to one-day, ten-day and 30-day values using mean variability factors. LS&F mean cyanide is calculated by applying the ratios of removals L&S and LS&F as discussed previously for LS&F metals limitations. The cyanide performance was arrived at by using the average metal variability factors. The treatment method used here is cyanide precipitation. Because cyanide precipitation is limited by the same physical processes as the metal precipitation, it is expected that the variabilities will be similar. Therefore, the average of the metal variability factors has been used as a basis for calculating the cyanide one-day, ten-day and thirty-day average treatment effectiveness values.

The filter performance for removing TSS as shown in Table VII-9 (page 221) yields a mean effluent concentration of 2.61 mg/l and calculates to a 10-day average of 4.33, 30-day average of 3.36 mg/l; a one-day maximum of 8.88. These calculated values more than amply support the classic thirty-day and one-day values of 10 mg/l and 15 mg/l, respectively, which are used for LS&F.

Although iron concentrations were decreased in some LS&F operations, some facilities using that treatment introduce iron compounds to aid settling. Therefore, the one-day, ten-day and 30-day values for iron at LS&F were held at the L&S level so as to not unduly penalize the operations which use the relatively less objectionable iron compounds to enhance removals of toxic metals.

The removal of additional fluoride by adding polishing filtration is suspect because of the high solubility of calcium fluoride. The one available data point appears to question the ability of filters to achieve high removals of additional fluoride. The fluoride levels demonstrated for L&S are used as the treatment effectiveness for LS&F.

MINOR TECHNOLOGIES

Several other treatment technologies were considered for possible application in this subcategory. These technologies are discussed here.

8. Flotation

Flotation is the process of causing particles such as metal hydroxides or oil to float to the surface of a tank where they can be concentrated and removed. This is accomplished by releasing gas bubbles which attach to the solid particles, increasing their buoyancy and causing them to float. In principle, this process is the opposite of sedimentation. Figure VII-23 (page 259) shows one type of flotation system.

Flotation is used primarily in the treatment of wastewater streams that carry heavy loads of finely divided suspended solids or oil. Solids having a specific gravity only slightly greater than 1.0, which would require abnormally long sedimentation times, may be removed in much less time by flotation. Dissolved air flotation is of greatest interest in removing oil from water and is less effective in removing heavier precipitates.

This process may be performed in several ways: foam, dispersed air, dissolved air, gravity, and vacuum flotation are the most commonly used techniques. Chemical additives are often used to enhance the performance of the flotation process.

The principal difference among types of flotation is the method of generating the minute gas bubbles (usually air) in a suspension of water and small particles. Chemicals may be used to improve the efficiency with any of the basic methods.

Froth Flotation - Froth flotation is based on differences in the physiochemical properties in various particles. Wettability and surface properties affect the particles' ability to attach themselves to gas bubbles in an aqueous medium. In froth flotation, air is blown through the solution containing flotation reagents. The particles with water repellant surfaces stick to air bubbles as they rise and are brought to the surface. A mineralized froth layer, with mineral particles attached to air bubbles, is formed. Particles of other minerals which are readily wetted by water do not stick to air bubbles and remain in suspension.

Dispersed Air Flotation - In dispersed air flotation, gas bubbles are generated by introducing the air by means of mechanical agitation with impellers or by forcing air through porous media. Dispersed air flotation is used mainly in the metallurgical industry.

Dissolved Air Flotation - In dissolved air flotation, bubbles are produced by releasing air from a supersaturated solution under relatively high pressure. There are two types of contact between the gas bubbles and particles. The first type is predominant in the flotation of flocculated materials and involves the entrapment of rising gas bubbles in the flocculated particles as they increase in size. The bond between the bubble and particle is one of physical capture only. The second type of contact is one of adhesion. Adhesion results from the intermolecular attraction exerted at the interface between the solid particle and gaseous bubble.

Vacuum Flotation - This process consists of saturating the wastewater with air either directly in an aeration tank, or by permitting air to enter on the suction of a wastewater pump. A partial vacuum is applied, which causes the dissolved air to come out of solution as minute bubbles. The bubbles attach to solid particles and rise to the surface to form a scum blanket, which is normally removed by a skimming mechanism. Grit and other heavy solids that settle to the bottom are generally raked to a central sludge pump for removal. A typical vacuum flotation unit consists of a covered cylindrical tank in which a partial vacuum is maintained. The tank is equipped with scum and sludge removal mechanisms. The floating material is continuously swept to the tank periphery, automatically discharged into a scum trough, and removed from the unit by a pump also under partial vacuum. Auxiliary equipment includes an aeration tank for saturating the wastewater with air, a tank with a short retention time for removal of large bubbles, vacuum pumps, and sludge pumps.

Application and Performance. The primary variables for flotation design are pressure, feed solids concentration, and retention period. The suspended solids in the effluent decrease, and the concentration of solids in the float increases with increasing retention period. When the flotation process is used primarily for clarification, a retention period of 20 to 30 minutes usually is adequate for separation and concentration.

Advantages and Limitations. Some advantages of the flotation process are the high levels of solids separation achieved in many applications, the relatively low energy requirements, and the adaptability to meet the treatment requirements of different waste types. Limitations of flotation are that it often requires addition of chemicals to enhance process performance and that it generates large quantities of solid waste.

Operational Factors. Reliability: Flotation systems normally are very reliable with proper maintenance of the sludge collector mechanism and the motors and pumps used for aeration.

Maintainability: Routine maintenance is required on the pumps and motors. The sludge collector mechanism is subject to possible corrosion or breakage and may require periodic replacement.

Solid Waste Aspects: Chemicals are commonly used to aid the flotation process by creating a surface or a structure that can easily adsorb or entrap air bubbles. Inorganic chemicals, such as the aluminum and ferric salts, and activated silica, can bind the particulate matter together and create a structure that can entrap air bubbles. Various organic chemicals can change the nature of either the air-liquid interface or the solid-liquid interface, or both. These compounds usually collect on the interface to bring about the desired changes. The added chemicals plus the particles in solution combine to form a large volume of sludge which must be further treated or properly disposed.

Demonstration Status. Flotation is a fully developed process and is readily available for the treatment of a wide variety of industrial waste streams. Dissolved air flotation (DAF) equipment is installed at 23 canmaking plants. One plant uses DAF primarily for oil removal. Nineteen plants use DAF primarily for solids removal and secondarily for oil removal. Four plants use DAF for oil removal and solids removal in conjunction with other solids removal equipment.

9. Chemical Emulsion Breaking

Chemical treatment is often used to break stable oil-water (O-W) emulsions. An O-W emulsion consists of oil dispersed in water, stablized by electrical charges and emulsifying agents. A stable emulsion will not separate or break down without some form of treatment.

Once an emulsion is broken, the difference in specific gravities allows the oil to float to the surface of the water. Solids usually form a layer between the oil and water, since some oil is retained in the solids. The longer the retention time, the more complete and distinct the separation between the oil, solids, and water will be. Often other methods of gravity differential separation, such as air flotation or rotational separation (e.g., centrifugation), are used to enhance and speed separation. A schematic flow diagram of one type of application is shown in Figure VII-31 (page 267).

The major equipment required for chemical emulsion breaking includes: reaction chambers with agitators, chemical storage tanks, chemical feed systems, pump, and piping.

Emulsifiers may be used in the plant to aid in stabilizing or forming emulsions. Emulsifiers are surface-active agents which alter the characteristics of the oil and water interface. These surfactants have rather long polar molecules. One end of the molecule is particularly soluble in water (e.g., carboxyl, sulfate, hydroxyl, or sulfonate groups) and the other end is readily soluble in oils (an organic group which varies greatly with the different surfactant type). Thus, the surfactant emulsifies or suspends the organic material (oil) in water. Emulsifiers also lower the surface tension of the O-W emulsion as a result of solvation and ionic complexing. These emulsions must be destabilized in the treatment system.

Application and Performance. Emulsion breaking is applicable to waste streams containing emulsified oils or lubricants such as rolling and drawing emulsions.

Treatment of spent O-W emulsions involves the use of chemicals to break the emulsion followed by gravity differential separation. Factors to be considered for breaking emulsions are type of chemicals, dosage and sequence of addition, pH, mechanical shear and agitation, heat, and retention time.

Chemicals, e.g., polymers, alum, ferric chloride, and organic emulsion breakers, break emulsions by neutralizing repulsive charges between particles, precipitating or salting out emulsifying agents, or altering the interfacial film between the oil and water so it is readily broken. Reactive cations, e.g., H(+1), Al(+3), Fe(+3), and cationic polymers, are particularly effective in breaking dilute O-W emulsions. Once the charges have been neutralized or the interfacial film broken, the small oil droplets and suspended solids will be adsorbed on the surface of the floc that is formed, or break out and float to the top. Various types of emulsion-breaking chemicals are used for the various types of oils.

If more than one chemical is required, the sequence of addition can make quite a difference in both breaking efficiency and chemical dosages.

pH plays an important role in emulsion breaking, especially if cationic inorganic chemicals, such as alum, are used as coagulants. A depressed pH in the range of 2 to 4 keeps the aluminum ion in its most positive state where it can function most effectively for charge neutralization. After some of the oil is broken free and skimmed, raising the pH into the 6 to 8 range with lime or caustic will cause the aluminum to hydrolyze and precipitate as aluminum hydroxide. This floc entraps or adsorbs destablized oil droplets which can then be separated from the water phase. Cationic polymers can break emulsions over a wider pH range and thus avoid acid corrosion and the additional sludge generated from neutralization; however, an inorganic flocculant is usually required to supplement the polymer emulsion breaker's adsorptive properties.

Mixing is important in breaking O-W emulsions. Proper chemical feed and dispersion is required for effective results. Mixing also causes collisions which help break the emulsion, and subsequently helps to agglomerate droplets.

In all emulsions, the mix of two immiscible liquids has a specific gravity very close to that of water. Heating lowers the viscosity and increases the apparent specific gravity differential between oil and water. Heating also increases the frequency of droplet collisons, which helps to rupture the interfacial film. Chemical emulsion breaking efficiencies are shown in Table VII-30 (page 236).

Oil and grease and toxic organics removal performance data are shown in Tables VII-11 and VII-13 (pages 222 and 224). Data were obtained from sampling at operating plants and a review of the current literature. This type of treatment is proven to be reliable and is considered the current state-of-the-art for aluminum forming as well as canmaking emulsified oily wastewaters.

Advantages and Limitions. Advantages gained from the use of chemicals for breaking O-W emulsions are the high removal efficiency potential and the possibility of reclaiming the oily waste. Disadvantages are corrosion problems associated with Acid-alum systems, skilled operator requirements for batch treatment, chemical sludges produced, and poor cost-effectiveness for low oil concentrations.

Operational Factors. Reliability: Chemical emulsion breaking is a very reliable process. The main control parameters, pH and temperature, are fairly easy to control.

Maintainability: Maintenance is required on pumps, motors, and valves, as well as periodic cleaning of the treatment tank to remove any accumulated solids. Energy use is limited to mixers and pumps.

Solid Waste Aspects: The surface oil and oily sludge produced are usually hauled away by a licensed contractor. If the recovered oil has a sufficiently low percentage of water, it may be burned for its fuel value or processed and reused.

Demonstration Status. Chemical emulsion breaking (CEB) is a fully developed technology widely used in other industry segments, such as metal forming, that use oil-water emulsions. CEB is installed at 4 canmaking plants where it is used for oil removal on the total waste stream; 16 other plants use CEB as pretreatment for oil removal on the oily waste stream.

10. Carbon Adsorption

The use of activated carbon to remove dissolved organics from water and wastewater is a well demonstrated technology. It is one of the most efficient organic removal processes available. This sorption process is reversible, allowing activated carbon to be regenerated for reuse by the application of heat and steam or solvent. Activated carbon has also proved to be an effective adsorbent for many toxic metals, including mercury. Regeneration of carbon which has adsorbed significant metals, however, may be difficult.

The term activated carbon applies to any amorphous form of carbon that has been specially treated to give high adsorption capacities. Typical raw materials include coal, wood, coconut shells, petroleum base residues and char from sewage sludge pyrolysis. A carefully controlled process of dehydration, carbonization, and oxidation yields a product which is called activated carbon. This material has a high capacity for adsorption due primarily to the large surface area available for adsorption, 500-1500 m^2/g resulting from a large number of internal pores. Pore sizes generally range from 10-100 angstroms in radius.

Activated carbon removes contaminants from water by the process of adsorption, or the attraction and accumulation of one substance on the surface of another. Activated carbon preferentially adsorbs organic compounds and, because of this selectivity, is particularly effective in removing organic compounds from aqueous solution.

Carbon adsorption requires pretreatment to remove excess suspended solids, oils, and greases. Suspended solids in the influent should be less than 50 mg/l to minimize backwash requirements; a downflow carbon bed can handle much higher levels (up to 2000 mg/l), but requires frequent backwashing. Backwashing more than two or three times a day is not desirable; at 50 mg/l suspended solids one backwash will suffice. Oil and grease should be less than about 10 mg/l. A high level of dissolved inorganic material in the influent may cause problems with thermal carbon reactivation (i.e., scaling and loss of activity) unless appropriate preventive steps are taken. Such steps might include pH control, softening, or the use of an acid wash on the carbon prior to reactivation.

Activated carbon is available in both powdered and granular form. An adsorption column packed with granular activated carbon is shown in Figure VII-17 (page 253). Powdered carbon is less expensive per unit weight and may have slightly higher adsorption capacity, but it is more difficult to handle and to regenerate.

Application and Performance. Carbon adsorption is used to remove mercury from wastewaters. The removal rate is influenced by the mercury level in the influent to the adsorption unit. Removal levels found at three manufacturing facilities are shown in Table VII-24 (page 233). In the aggregate these data indicate that very low effluent levels could be attained from any raw waste by use of multiple adsorption stages. This is characteristic of adsorption processes.

Isotherm tests have indicated that activated carbon is very effective in adsorbing 65 percent of the organic priority pollutants and is reasonably effective for another 22 percent. Specifically, for the organics of particular interest, activated carbon was very effective in removing all phthalates. It was resonably effective on 1,1,1-trichloroethane, bis(2-chloroethyl)ether, and toluene.

Table VII-22 (page 231) summarizes the treatment effectiveness for most of the organic priority pollutants by activated carbon as compiled by EPA. Table VII-23 (page 232) summarizes classes of organic compounds together with examples of organics that are readily adsorbed on carbon. Table VII-24 lists the effectiveness of activated carbon for the removal of mercury.

Advantages and Limitations. The major benefits of carbon treatment include applicability to a wide variety of organics, and high removal efficiency. Inorganics such as cyanide, chromium, and mercury are also removed effectively. Variations in concentration and flow rate are well tolerated. The system is compact, and recovery of adsorbed materials is sometimes practical. However, destruction of adsorbed compounds often occurs during thermal regeneration. If carbon cannot be thermally desorbed, it must be disposed of along with any adsorbed pollutants. The capital and operating costs of thermal regeneration are relatively high. Cost surveys show that thermal regeneration is generally economical when carbon usage exceeds about 1,000 lb/day. Carbon cannot remove low molecular weight or highly soluble organics. It also has a low tolerance for suspended solids, which must be removed to at least 50 mg/l in the influent water.

Operational Factors. Reliability: This system should be very reliable with upstream protection and proper operation and maintenance procedures.

Maintainability: This system requires periodic regeneration or replacement of spent carbon and is dependent upon raw waste load and process efficiency.

Solid Waste Aspects: Solid waste from this process is contaminated activated carbon that requires disposal. Carbon undergoes regeneration, which reduces the solid waste problem by reducing the frequency of carbon replacement.

Demonstration Status. Carbon adsorption systems have been demonstrated to be practical and economical in reducing COD, BOD and related parameters in secondary municipal and industrial wastewaters; in removing toxic or refractory organics from isolated industrial wastewaters; in removing and recovering certain organics from wastewaters; and in the removing and some times recovering, of selected inorganic chemicals from aqueous wastes. Carbon adsorption is a viable and economic process for organic waste streams containing up to 1 to 5 percent of refractory or toxic organics. Its applicability for removal of inorganics such as metals has also been demonstrated.

11. Centrifugation

Centrifugation is the application of centrifugal force to separate solids and liquids in a liquid-solid mixture or to effect concentration of the solids. The application of centrifugal force is effective because of the density differential normally found between the insoluble solids and the liquid in which they are contained. As a waste treatment procedure, centrifugation is applied to dewatering of sludges. One type of centrifuge is shown in Figure VII-18 (page 254).

There are three common types of centrifuges: the disc, basket, and conveyor type. All three operate by removing solids under the influence of centrifugal force. The fundamental difference between the three types is the method by which solids are collected in and discharged from the bowl.

In the disc centrifuge, the sludge feed is distributed between narrow channels that are present as spaces between stacked conical discs. Suspended particles are collected and discharged continuously through small orifices in the bowl wall. The clarified effluent is discharged through an overflow weir.

A second type of centrifuge which is useful in dewatering sludges is the basket centrifuge. In this type of centrifuge, sludge feed is introduced at the bottom of the basket, and solids collect at the bowl wall while clarified effluent overflows the lip ring at the top. Since the basket centrifuge does not have provision for continuous discharge of collected cake, operation requires interruption of the feed for cake discharge for a minute or two in a 10 to 30 minute overall cycle.

The third type of centrifuge commonly used in sludge dewatering is the conveyor type. Sludge is fed through a stationary feed pipe into a rotating bowl in which the solids are settled out against the bowl wall by centrifugal force. From the bowl wall, they are moved by a screw to the end of the machine, at which point whey are discharged. The liquid effluent is discharged through ports after passing the length of the bowl under centrifugal force.

Application And Performance. Virtually all industrial waste treatment systems producing sludge can use centrifugation to dewater it. Centrifugation is currently being used by a wide range of industrial concerns.

The performance of sludge dewatering by centrifugation depends on the feed rate, the rotational velocity of the drum, and the sludge composition and concentration. Assuming proper design and operation, the solids content of the sludge can be increased to 20-35 percent.

Advantages And Limitations. Sludge dewatering centrifuges have minimal space requirements and show a high degree of effluent clarification. The operation is simple, clean, and relatively inexpensive. The area required for a centrifuge system installation is less than that required for a filter system or sludge drying bed of equal capacity, and the initial cost is lower.

Centrifuges have a high power cost that partially offsets the low initial cost. Special consideration must also be given to providing sturdy foundations and soundproofing because of the vibration and noise that result from centrifuge operation. Adequate electrical power must also be provided since large motors are required. The major difficulty encountered in the operation of centrifuges has been the disposal of the concentrate which is relatively high in suspended, nonsettling solids.

Operational Factors. Reliability: Centrifugation is highly reliable with proper control of factors such as sludge feed, consistency, and temperature. Pretreatment such as grit removal and coagulant addition may be necessary, depending on the composition of the sludge and on the type of centrifuge employed.

Maintainability: Maintenance consists of periodic lubrication, cleaning, and inspection. The frequency and degree of inspection required varies depending on the type of sludge solids being dewatered and the maintenance service conditions. If the sludge is abrasive, it is recommended that the first inspection of the rotating assembly be made after approximately 1,000 hours of operation. If the sludge is not abrasive or corrosive, then the initial inspection might be delayed. Centrifuges not equipped with a continuous sludge discharge system require periodic shutdowns for manual sludge cake removal.

Solid Waste Aspects: Sludge dewatered in the centrifugation process may be disposed of by landfill. The clarified effluent (centrate), if high in dissolved or suspended solids, may require further treatment prior to discharge.

Demonstration Status. Centrifugation is currently used in a great many commercial applications to dewater sludge. Work is underway to improve the efficiency, increase the capacity, and lower the costs associated with centrifugation.

12. Coalescing

The basic principle of coalescence involves the preferential wetting of a coalescing medium by oil droplets which accumulate on the medium and then rise to the surface of the solution as they combine to form larger particles. The most important requirements for coalescing media are wettability for oil and large surface area. Monofilament line is sometimes used as a coalescing medium.

Coalescing stages may be integrated with a wide variety of gravity oil separation devices, and some systems may incorporate several coalescing stages. In general a preliminary oil skimming step is desirable to avoid overloading the coalescer.

One commercially marketed system for oily waste treatment combines coalescing with inclined plate separation and filtration. In this system, the oily wastes flow into an inclined plate settler. This unit consists of a stack of inclined baffle plates in a cylindrical container with an oil collection chamber at the top. The oil droplets rise and impinge upon the undersides of the plates. They then migrate upward to a guide rib which directs the oil to the oil collection chamber, from which oil is discharged for reuse or disposal.

The oily water continues on through another cylinder containing replaceable filter cartridges, which remove suspended particles from the waste. From there the wastewater enters a final cylinder in which the coalescing material is housed. As the oily water passes through the many small, irregular, continuous passages in the coalescing material, the oil droplets coalesce and rise to an oil collection chamber.

Application and Performance. Coalescing is used to treat oily wastes which do not separate readily in simple gravity systems. The three stage system described above has achieved effluent concentrations of 10-15 mg/l oil and grease from raw waste concentrations of 1000 mg/l or more.

Advantages and Limitations. Coalescing allows removal of oil droplets too finely dispersed for conventional gravity separation-skimming technology. It also can significantly reduce the residence times (and therefore separator volumes) required to achieve separation of oil from some wastes. Because of its simplicity, coalescing provides generally high reliability and low capital and operating costs. Coalescing is not generally effective in removing soluble or chemically stabilized emulsified oils. To avoid plugging, coalescers must be protected by pretreatment from very high concentrations of free oil and grease and suspended solids. Frequent replacement of prefilters may be necessary when raw waste oil concentrations are high.

Operational Factors. Reliability: Coalescing is inherently highly reliable since there are no moving parts, and the coalescing substrate (monofilament, etc.) is inert in the process and therefore not subject to frequent regeneration or replacement requirements. Large loads or inadequate pretreatment, however, may result in plugging or bypass of coalescing stages.

Maintainability: Maintenance requirements are generally limited to replacement of the coalescing medium on an infrequent basis.

Solid Waste Aspects: No appreciable solid waste is generated by this process.

Demonstration Status. Coalescing has been fully demonstrated in industries generating oily wastewater.

13. Cyanide Oxidation by Chlorine

Cyanide oxidation using chlorine is widely used in industrial waste treatment to oxidize cyanide. Chlorine can be utilized in either the elemental or hypochlorite forms. This classic procedure can be illustrated by the following two step chemical reaction:

1. $Cl_2 + NaCN + 2NaOH \rightarrow NaCNO + 2NaCl + H_2O$

2. $3Cl_2 + 6NaOH + 2NaCNO \rightarrow 2NaHCO_3 + N_2 + 6NaCl + 2H_2O$

The reaction presented as equation (2) for the oxidation of cyanate is the final step in the oxidation of cyanide. A complete system for the alkaline chlorination of cyanide is shown in Figure VII-19 (page 255).

The alkaline chlorination process oxidizes cyanides to carbon dioxide and nitrogen. The equipment often consists of an equalization tank followed by two reaction tanks, although the reaction can be carried out in a single tank. Each tank has an electronic recorder-controller to maintain required conditions with respect to pH and oxidation reduction potential (ORP). In the first reaction tank, conditions are adjusted to oxidize cyanides to cyanates. To effect the reaction, chlorine is metered to the reaction tank as required to maintain the ORP in the range of 350 to 400 millivolts, and 50 percent aqueous caustic soda is added to maintain a pH range of 9.5 to 10. In the second reaction tank, conditions are maintained to oxidize cyanate to carbon dioxide and nitrogen. The desirable ORP and pH for this reaction are 600 millivolts and a pH of 8.0. Each of the reaction tanks is equipped with a propeller agitator designed to provide approximately one turnover per minute. Treatment by the batch process is accomplished by using two tanks, one for collection of water over a specified time period, and one tank for the treatment of an accumulated batch. If dumps of concentrated wastes are frequent, another tank may be required to equalize the flow to the treatment tank. When the holding tank is full, the liquid is transferred to the reaction tank for treatment. After treatment, the supernatant is discharged and the sludges are collected for removal and ultimate disposal.

Application and Performance. The oxidation of cyanide waste by chlorine is a classic process and is found in most industrial plants using cyanide. This process is capable of achieving effluent levels that are nondetectable. The process is potentially applicable to canmaking facilities where cyanide is a component in conversion coating formulations.

Advantages and Limitations. Some advantages of chlorine oxidation for handling process effluents are operation at ambient temperature, suitability for automatic control, and low cost. Disadvantages include the need for careful pH control, possible chemical interference in the treatment of mixed wastes, and the potential hazard of storing and handling chlorine gas.

Operational Factors. Reliability: Chlorine oxidation is highly reliable with proper monitoring and control, and proper pretreatment to control interfering substances.

Maintainability: Maintenance consists of periodic removal of sludge and recalibration of instruments.

Solid Waste Aspects: There is no solid waste problem associated with chlorine oxidation.

Demonstration Status. The oxidation of cyanide wastes by chlorine is a widely used process in plants using cyanide in cleaning and metal processing baths.

14. Cyanide Oxidation by Ozone

Ozone is a highly reactive oxidizing agent which is approximately ten times more soluble than oxygen on a weight basis in water. Ozone may be produced by several methods, but the silent electrical discharge method is predominant in the field. The silent electrical discharge process produces ozone by passing oxygen or air between electrodes separated by an insulating material. A complete ozonation system is represented in Figure VII-20 (page 256).

Application and Performance. Ozonation has been applied commercially to oxidize cyanides, phenolic chemicals, and organo-metal complexes. Its applicability to photographic wastewaters has been studied in the laboratory with good results. Ozone is used in industrial waste treatment primarily to oxidize cyanide to cyanate and to oxidize phenols and dyes to a variety of colorless nontoxic products.

Oxidation of cyanide to cyanate is illustrated below:

$$CN^- + O_3 \rightarrow CNO^- + O_2$$

Continued exposure to ozone will convert the cyanate formed to carbon dioxide and ammonia; however, this is not economically practical.

Ozone oxidation of cyanide to cyanate requires 1.8 to 2.0 pounds ozone per pound of CN-; complete oxidation requires 4.6 to 5.0

pounds ozone per pound of CN-. Zinc, copper, and nickel cyanides are easily destroyed to a nondetectable level, but cobalt and iron cyanides are more resistant to ozone treatment.

Advantages and Limitations. Some advantages of ozone oxidation for handling process effluents are its suitability to automatic control and on-site generation and the fact that reaction products are not chlorinated organics and no dissolved solids are added in the treatment step. Ozone in the presence of activated carbon, ultraviolet, and other promoters shows promise of reducing reaction time and improving ozone utilization, but the process at present is limited by high capital expense, possible chemical interference in the treatment of mixed wastes, and an energy requirement of 25 kwh/kg of ozone generated. Cyanide is not economically oxidized beyond the cyanate form.

Operational Factors. Reliability: Ozone oxidation is highly reliable with proper monitoring and control, and proper pretreatment to control interfering substances.

Maintainability: Maintenance consists of periodic removal of sludge, and periodic renewal of filters and desiccators required for the input of clean dry air; filter life is a function of input concentrations of detrimental constituents.

Solid Waste Aspects: Pretreatment to eliminate substances which will interfere with the process may be necessary. Dewatering of sludge generated in the ozone oxidation process or in an "in line" process may be desirable prior to disposal.

15. Cyanide Oxidation by Ozone and UV Radiation

One of the modifications of the ozonation process is the simultaneous application of ultraviolet light and ozone for the treatment of wastewater, including treatment of halogenated organics. The combined action of these two forms produces reactions by photolysis, photosensitization, hydroxylation, oxygenation and oxidation. The process is unique because several reactions and reaction species are active simultaneously.

Ozonation is facilitated by ultraviolet absorption because both the ozone and the reactant molecules are raised to a higher energy state so that they react more rapidly. In addition, free radicals for use in the reaction are readily hydrolyzed by the water present. The energy and reaction intermediates created by the introduction of both ultraviolet and ozone greatly reduce the amount of ozone required compared with a system using ozone alone. Figure VII-21 (page 257) shows a three-stage UV-ozone system. A system to treat mixed cyanides requires pretreatment that involves chemical coagulation, sedimentation, clarification, equalization, and pH adjustment.

Application and Performance. The ozone-UV radiation process was developed primarily for cyanide treatment in the electroplating and color photo-processing areas. It has been successfully applied to mixed cyanides and organics from organic chemicals manufacturing processes. The process is particularly useful for treatment of complexed cyanides such as ferricyanide, copper cyanide and nickel cyanide, which are resistant to ozone alone.

Ozone combined with UV radiation is a relatively new technology. Four units are currently in operation and all four treat cyanide bearing waste.

Ozone-UV treatment could be used in canmaking plants to destroy cyanide present in waste streams from some conversion coating operations.

16. Cyanide Oxidation by Hydrogen Peroxide

Hydrogen peroxide oxidation removes both cyanide and metals in cyanide containing wastewaters. In this process, cyanide bearing waters are heated to 49 - 54°C (120 - 130°F) and the pH is adjusted to 10.5 - 11.8. Formalin (37 percent formaldehyde) is added while the tank is vigorously agitated. After 2-5 minutes, a proprietary peroxygen compound (41 percent hydrogen peroxide with a catalyst and additives) is added. After an hour of mixing, the reaction is complete. The cyanide is converted to cyanate and the metals are precipitated as oxides or hydroxides. The metals are then removed from solution by either settling or filtration.

The main equipment required for this process is two holding tanks equipped with heaters and air spargers or mechanical stirrers. These tanks may be used in a batch or continuous fashion, with one tank being used for treatment while the other is being filled. A settling tank or a filter is needed to concentrate the precipitate.

Application and Performance. The hydrogen peroxide oxidation process is applicable to cyanide bearing wastewaters, especially those containing metal-cyanide complexes. In terms of waste reduction performance, this process can reduce total cyanide to less than 0.1 mg/l and the zinc or cadmium to less than 1.0 mg/l.

Advantages and Limitations. Chemical costs are similar to those for alkaline chlorination using chlorine and lower than those for treatment with hypochlorite. All free cyanide reacts and is completely oxidized to the less toxic cyanate state. In addition, the metals precipitate and settle quickly, and they may be recoverable in many instances. However, the process requires energy expenditures to heat the wastewater prior to treatment.

Demonstration Status. This treatment process was introduced in 1971 and is used in several facilities.

17. Evaporation

Evaporation is a concentration process. Water is evaporated from a solution, increasing the concentration of solute in the remaining solution. If the resulting water vapor is condensed back to liquid water, the evaporation-condensation process is called distillation. However, to be consistent with industry terminology, evaporation is used in this report to describe both processes. Both atmospheric and vacuum evaporation are commonly used in industry today. Specific evaporation techniques are shown in Figure VII-22 (page 258) and discussed below.

Atmospheric evaporation could be accomplished simply by boiling the liquid. However, to aid evaporation, heated liquid is sprayed on an evaporation surface, and air is blown over the surface and subsequently released to the atmosphere. Thus, evaporation occurs by humidification of the air stream, similar to a drying process. Equipment for carrying out atmospheric evaporation is quite similar for most applications. The major element is generally a packed column with an accumulator bottom. Accumulated wastewater is pumped from the base of the column, through a heat exchanger, and back into the top of the column, where it is sprayed into the packing. At the same time, air drawn upward through the packing by a fan is heated as it contacts the hot liquid. The liquid partially vaporizes and humidifies the air stream. The fan then blows the hot, humid air to the outside atmosphere. A scrubber is often unnecessary because the packed column itself acts as a scrubber.

Another form of atmospheric evaporator also works on the air humidification principle, but the evaporated water is recovered for reuse by condensation. These air humidification techniques operate well below the boiling point of water and can utilize waste process heat to supply the energy required.

In vacuum evaporation, the evaporation pressure is lowered to cause the liquid to boil at reduced temperature. All of the water vapor is condensed and, to maintain the vacuum condition, noncondensible gases (air in particular) are removed by a vacuum pump. Vacuum evaporation may be either single or double effect. In double effect evaporation, two evaporators are used, and the water vapor from the first evaporator (which may be heated by steam) is used to supply heat to the second evaporator. As it

---

tiles. Figure VII-28 (page 264) shows the construction of a drying bed.

Drying beds are usually divided into sectional areas approximately 7.5 meters (25 ft) wide x 30 to 60 meters (100 to 200 ft) long. The partitions may be earth embankments, but more often are made of planks and supporting grooved posts.

To apply liquid sludge to the sand bed, a closed conduit or a pressure pipeline with valved outlets at each sand bed section is often employed. Another method of application is by means of an open channel with appropriately placed side openings which are controlled by slide gates. With either type of delivery system, a concrete splash slab should be provided to receive the falling sludge and prevent erosion of the sand surface.

Where it is necessary to dewater sludge continuously throughout the year regardless of the weather, sludge beds may be covered with a fiberglass reinforced plastic or other roof. Covered drying beds permit a greater volume of sludge drying per year in most climates because of the protection afforded from rain or snow and because of more efficient control of temperature. Depending on the climate, a combination of open and enclosed beds will provide maximum utilization of the sludge bed drying facilities.

Application and Performance. Sludge drying beds are a means of dewatering sludge from clarifiers and thickeners. They are widely used both in municipal and industrial treatment facilities.

Dewatering of sludge on sand beds occurs by two mechanisms: filtration of water through the bed and evaporation of water as a result of radiation and convection. Filtration is generally complete in one to two days and may result in solids concentrations as high as 15 to 20 percent. The rate of filtration depends on the drainability of the sludge.

The rate of air drying of sludge is related to temperature, relative humidity, and air velocity. Evaporation will proceed at a constant rate to a critical moisture content, then at a falling rate to an equilibrium moisture content. The average evaporation rate for a sludge is about 75 percent of that from a free water surface.

Advantages and Limitations. The main advantage of sludge drying beds over other types of sludge dewatering is the relatively low cost of construction, operation, and maintenance.

supplies heat, the water vapor from the first evaporator condenses. Approximately equal quantities of wastewater are evaporated in each unit; thus, the double effect system evaporates twice the amount of water that a single effect system does, at nearly the same cost in energy but with added capital cost and complexity. The double effect technique is thermodynamically possible because the second evaporator is maintained at lower pressure (higher vacuum) and, therefore, lower evaporation temperature. Another means of increasing energy efficiency is vapor recompression (thermal or mechanical), which enables heat to be transferred from the condensing water vapor to the evaporating wastewater. Vacuum evaporation equipment may be classified as submerged tube or climbing film evaporation units.

In the most commonly used submerged tube evaporator, the heating and condensing coil are contained in a single vessel to reduce capital cost. The vacuum in the vessel is maintained by an eductor-type pump, which creates the required vacuum by the flow of the condenser cooling water through a venturi. Waste water accumulates in the bottom of the vessel, and it is evaporated by means of submerged steam coils. The resulting water vapor condenses as it contacts the condensing coils in the top of the vessel. The condensate then drips off the condensing coils into a collection trough that carries it out of the vessel. Concentrate is removed from the bottom of the vessel.

The major elements of the climbing film evaporator are the evaporator, separator, condenser, and vacuum pump. Wastewater is "drawn" into the system by the vacuum so that a constant liquid level is maintained in the separator. Liquid enters the steam-jacketed evaporator tubes, and part of it evaporates so that a mixture of vapor and liquid enters the separator. The design of the separator is such that the liquid is continuously circulated from the separator to the evaporator. The vapor entering the separator flows out through a mesh entrainment separator to the condenser, where it is condensed as it flows down through the condenser tubes. The condensate, along with any entrained air, is pumped out of the bottom of the condenser by a liquid ring vacuum pump. The liquid seal provided by the condensate keeps the vacuum in the system from being broken.

Application and Performance. Both atmospheric and vacuum evaporation are used in many industrial plants, mainly for the concentration and recovery of process solutions. Many of these evaporators also recover water for rinsing. Evaporation has also been applied to recovery of phosphate metal cleaning solutions.

In theory, evaporation should yield a concentrate and a deionized condensate. Actually, carry-over has resulted in condensate metal concentrations as high as 10 mg/l, although the usual level is less than 3 mg/l, pure enough for most final rinses. The condensate may also contain organic brighteners and antifoaming agents. These can be removed with an activated carbon bed, if necessary. Samples from one plant showed 1,900 mg/l zinc in the feed, 4,570 mg/l in the concentrate, and 0.4 mg/l in the condensate. Another plant had 416 mg/l copper in the feed and 21,800 mg/l in the concentrate. Chromium analysis for that plant indicated 5,060 mg/l in the feed and 27,500 mg/l in the concentrate. Evaporators are available in a range of capacities, typically from 15 to 75 gph, and may be used in parallel arrangements for processing of higher flow rates.

Advantages and Limitations. Advantages of the evaporation process are that it permits recovery of a wide variety of process chemicals, and it is often applicable to concentration or removal of compounds which cannot be accomplished by any other means. The major disadvantage is that the evaporation process consumes relatively large amounts of energy for the evaporation of water. However, the recovery of waste heat from many industrial processes (e.g., diesel generators, incinerators, boilers and furnaces) should be considered as a source of this heat for a totally integrated evaporation system. Also, in some cases solar heating could be inexpensively and effectively applied to evaporation units. For some applications, pretreatment may be required to remove solids or bacteria which tend to cause fouling in the condenser or evaporator. The buildup of scale on the evaporator surfaces reduces the heat transfer efficiency and may present a maintenance problem or increase operating cost. However, it has been demonstrated that fouling of the heat transfer surfaces can be avoided or minimized for certain dissolved solids by maintaining a seed slurry which provides preferential sites for precipitate deposition. In addition, low temperature differences in the evaporator will eliminate nucleate boiling and supersaturation effects. Steam distillable impurities in the process stream are carried over with the product water and must be handled by pre or post treatment.

Operational Factors. Reliability: Proper maintenance will ensure a high degree of reliability for the system. Without such attention, rapid fouling or deterioration of vacuum seals may occur, especially when handling corrosive liquids.

Maintainability: Operating parameters can be automatically controlled. Pretreatment may be required, as well as periodic cleaning of the system. Regular replacement of seals, especially in a corrosive environment, may be necessary.

Solid Waste Aspects: With only a few exceptions, the process does not generate appreciable quantities of solid waste.

Demonstration Status. Evaporation is a fully developed, commercially available wastewater treatment system. It is used extensively to recover plating chemicals in the electroplating industry and a pilot scale unit has been used in connection with phosphating of aluminum. Proven performance in silver recovery indicates that evaporation could be a useful treatment operation for the photographic industry, as well as for metal finishing.

18. Gravity Sludge Thickening

In the gravity thickening process, dilute sludge is fed from a primary settling tank or clarifier to a thickening tank where rakes stir the sludge gently to densify it and to push it to a central collection well. The supernatant is returned to the primary settling tank. The thickened sludge that collects on the bottom of the tank is pumped to dewatering equipment or hauled away. Figure VII-24 (page 260) shows the construction of a gravity thickener.

Application and Performance. Thickeners are generally used in facilities where the sludge is to be further dewatered by a compact mechanical device such as a vacuum filter or centrifuge. Doubling the solids content in the thickener substantially reduces capital and operating cost of the subsequent dewatering device and also reduces cost for hauling. The process is potentially applicable to almost any industrial plant.

Organic sludges from sedimentation units of one to two percent solids concentration can usually be gravity thickened to six to ten percent; chemical sludges can be thickened to four to six percent.

Advantages and Limitations. The principal advantage of a gravity sludge thickening process is that it facilitates further sludge dewatering. Other advantages are high reliability and minimum maintenance requirements.

Limitations of the sludge thickening process are its sensitivity to the flow rate through the thickener and the sludge removal rate. These rates must be low enough not to disturb the thickened sludge.

Operational Factors. Reliability: Reliability is high with proper design and operation. A gravity thickener is designed on the basis of square feet per pound of solids per day, in which the required surface area is related to the solids entering and leaving the unit. Thickener area requirements are also expressed in terms of mass loading, grams of solids per square meter per day (lbs/sq ft/day).

Maintainability: Twice a year, a thickener must be shut down for lubrication of the drive mechanisms. Occasionally, water must be pumped back through the system in order to clear sludge pipes.

Solid Waste Aspects: Thickened sludge from a gravity thickening process will usually require further dewatering prior to disposal, incineration, or drying. The clear effluent may be recirculated in part, or it may be subjected to further treatment prior to discharge.

Demonstration Status. Gravity sludge thickeners are used throughout industry to reduce water content to a level where the sludge may be efficiently handled. Further dewatering is usually practiced to minimize costs of hauling the sludge to approved landfill areas. Sludge thickening is used in seven coil coating plants.

19. Insoluble Starch Xanthate

Insoluble starch xanthate is essentially an ion exchange medium used to remove dissolved heavy metals from wastewater. The water may then either be reused (recovery application) or discharged (end-of-pipe application). In a commercial electroplating operation, starch xanthate is coated on a filter medium. Rinse water containing dragged out heavy metals is circulated through the filters and then reused for rinsing. The starch-heavy metal complex is disposed of and replaced periodically. Laboratory tests indicate that recovery of metals from the complex is feasible, with regeneration of the starch xanthate. Besides electroplating, starch xanthate is potentially applicable to coil coating, porcelain enameling, copper fabrication, and any other industrial plants where dilute metal wastewater streams are generated. Its present use is limited to one electroplating plant.

20. Ion Exchange

Ion exchange is a process in which ions, held by electrostatic forces to charged functional groups on the surface of the ion exchange resin, are exchanged for ions of similar charge from the solution in which the resin is immersed. This is classified as a sorption process because the exchange occurs on the surface of the resin, and the exchanging ion must undergo a phase transfer from solution phase to solid phase. Thus, ionic contaminants in a waste stream can be exchanged for the harmless ions of the resin.

Although the precise technique may vary slightly according to the application involved, a generalized process description follows. The wastewater stream being treated passes through a filter to remove any solids, then flows through a cation exchanger which contains the ion exchange resin. Here, metallic impurities such as copper, iron, and trivalent chromium are retained. The stream then passes through the anion exchanger and its associated resin. Hexavalent chromium, for example, is retained in this stage. If one pass does not reduce the contaminant levels sufficiently, the stream may then enter another series of exchangers. Many ion exchange systems are equipped with more than one set of exchangers for this reason.

The other major portion of the ion exchange process concerns the regeneration of the resin, which now holds those impurities retained from the waste stream. An ion exchange unit with in-place regeneration is shown in Figure VII-25 (page 261). Metal ions such as nickel are removed by an acid, cation exchange resin, which is regenerated with hydrochloric or sulfuric acid, replacing the metal ion with one or more hydrogen ions. Anions such as dichromate are removed by a basic, anion exchange resin, which is regenerated with sodium hydroxide, replacing the anion with one or more hydroxyl ions. The three principal methods employed by industry for regenerating the spent resin are:

A) Replacement Service: A regeneration service replaces the spent resin with regenerated resin, and regenerates the spent resin at its own facility. The service then has the problem of treating and disposing of the spent regenerant.

B) In-Place Regeneration: Some establishments may find it less expensive to do their own regeneration. The spent resin column is shut down for perhaps an hour, and the spent resin is regenerated. This results in one or more waste streams which must be treated in an appropriate manner. Regeneration is performed as the resins require it, usually every few months.

C) Cyclic Regeneration: In this process, the regeneration of the spent resins takes place within the ion exchange unit itself in alternating cycles with the ion removal process. A regeneration frequency of twice an hour is typical. This very short cycle time permits operation with a very small quantity of resin and with fairly concentrated solutions, resulting in a very compact system. Again, this process varies according to application, but the regeneration cycle generally begins with caustic being pumped through the anion exchanger, carrying out hexavalent chromium, for example, as sodium dichromate. The sodium dichromate stream then passes through a cation exchanger, converting the sodium dichromate to chromic acid. After concentration by evaporation or other means, the chromic acid can be returned to the process line. Meanwhile, the cation exchanger is regenerated with sulfuric acid, resulting in a waste acid stream containing the metallic impurities removed earlier. Flushing the exchangers with water completes the cycle. Thus, the wastewater is purified and, in this example, chromic acid is recovered. The ion exchangers, with newly regenerated resin, then enter the ion removal cycle again.

Application and Performance. The list of pollutants for which the ion exchange system has proven effective includes aluminum, arsenic, cadmium, chromium (hexavalent and trivalent), copper, cyanide, gold, iron, lead, manganese, nickel, selenium, silver, tin, zinc, and more. Thus, it can be applied to a wide variety of industrial concerns. Because of the heavy concentrations of metals in their wastewater, the metal finishing industries utilize ion exchange in several ways. As an end-of-pipe treatment, ion exchange is certainly feasible, but its greatest value is in recovery applications. It is commonly used as an integrated treatment to recover rinse water and process chemicals. Some electroplating facilities use ion exchange to concentrate and purify plating baths. Also, many industrial concerns, including a number of coil coating plants, use ion exchange to reduce salt concentrations in incoming water sources.

Ion exchange is highly efficient at recovering metal bearing solutions. Recovery of chromium, nickel, phosphate solution, and sulfuric acid from anodizing is commercial. A chromic acid recovery efficiency of 99.5 percent has been demonstrated. Typical data for purification of rinse water have been reported and are displayed in Table VII-25 (page 233).

Ion exchange is a versatile technology applicable to a great many situations. This flexibility, along with its compact nature and performance, makes ion exchange a very effective method of waste water treatment. However, the resins in these systems can prove to be a limiting factor. The thermal limits of the anion resins, generally in the vicinity of 60°C, could prevent its use in certain situations. Similarly, nitric acid, chromic acid, and hydrogen peroxide can all damage the resins, as will iron, manganese, and copper when present with sufficient concentrations of dissolved oxygen. Removal of a particular trace contaminant may be uneconomical because of the presence of other ionic species that are preferentially removed. The regeneration of the resins presents its own problems. The cost of the regenerative chemicals can be high. In addition, the waste streams originating from the regeneration process are extremely high in pollutant concentrations, although low in volume. These must be further processed for proper disposal.

Operational Factors. Reliability: With the exception of occasional clogging or fouling of the resins, ion exchange has proved to be a highly dependable technology.

Maintainability: Only the normal maintenance of pumps, valves, piping and other hardware used in the regeneration process is required.

Solid Waste Aspects: Few, if any, solids accumulate within the ion exchangers, and those which do appear are removed by the regeneration process. Proper prior treatment and planning can eliminate solid buildup problems altogether. The brine resulting from regeneration of the ion exchange resin most usually must be treated to remove metals before discharge. This can generate solid waste.

Demonstration Status. All of the applications mentioned in this document are available for commercial use, and industry sources estimate the number of units currently in the field at well over 120. The research and development in ion exchange is focusing on improving the quality and efficiency of the resins, rather than new applications. Work is also being done on a continuous regeneration process whereby the resins are contained on a fluid-transfusible belt. The belt passes through a compartmented tank with ion exchange, washing, and regeneration sections. The resins are therefore continually used and regenerated. No such system, however, has been reported beyond the pilot stage.

21. Membrane Filtration

Membrane filtration is a treatment system for removing precipitated metals from a wastewater stream. It must therefore be preceded by those treatment techniques which will properly prepare the wastewater for solids removal. Typically, a membrane filtration unit is preceded by pH adjustment or sulfide addition for precipitation of the metals. These steps are followed by the addition of a proprietary chemical reagent which causes the precipitate to be nongelatinous, easily dewatered, and highly stable. The resulting mixture of pretreated wastewater and reagent is continuously recirculated through a filter module and back into a recirculation tank. The filter module contains tubular membranes. While the reagent-metal hydroxide precipitate mixture flows through the inside of the tubes, the water and any dissolved salts permeate the membrane. When the recirculating slurry reaches a concentration of 10 to 15 percent solids, it is pumped out of the system as sludge.

Application and Performance. Membrane filtration appears to be applicable to any wastewater or process water containing metal ions which can be precipitated using hydroxide, sulfide or carbonate precipitation. It could function as the primary treatment system, but also might find application as a polishing treatment (after precipitation and settling) to ensure continued compliance with metals limitations. Membrane filtration systems are being used in a number of industrial applications, particularly in the metal finishing area. They have also been used for heavy metals removal in the metal fabrication industry and the paper industry.

In the performance predictions for this technology, pollutant concentrations are reduced to the levels shown in Table VII-26 (page 234) unless lower levels are present in the influent stream.

A major advantage of the membrane filtration system is that installations can use most of the conventional end-of-pipe systems that may already be in place. Removal efficiencies are claimed to be excellent, even with sudden variation of pollutant input rates; however, the effectiveness of the membrane filtration system can be limited by clogging of the filters. Because pH changes in the waste stream greatly intensify clogging problems, the pH must be carefully monitored and controlled. Clogging can force the shutdown of the system and may interfere with production. In addition, relatively high capital cost of this system may limit its use.

Operational Factors. Reliability: Membrane filtration has been shown to be a very reliable system, provided that the pH is strictly controlled. Improper pH can result in the clogging of the membrane. Also, surges in the flow rate of the waste stream must be controlled in order to prevent solids from passing through the filter and into the effluent.

Maintainability: The membrane filters must be regularly monitored, and cleaned or replaced as necessary. Depending on the composition of the waste stream and its flow rate, frequent cleaning of the filters may be required. Flushing with hydrochloric acid for 6-24 hours will usually suffice. In addition, the routine maintenance of pumps, valves, and other plumbing is required.

Solid Waste Aspects: When the recirculating reagent-precipitate slurry reaches 10 to 15 percent solids, it is pumped out of the system. It can then be disposed of directly or it can undergo a dewatering process. Because this sludge contains toxic metals, it requires proper disposal.

Demonstration Status. There are more than 25 membrane filtration systems presently in use on metal finishing and similar wastewaters. Bench scale and pilot studies are being run in an attempt to expand the list of pollutants for which this system is known to be effective. A unit has been installed at one coil coating plant based on these tests.

22. Peat Adsorption

Peat moss is a complex natural organic material containing lignin and cellulose as major constituents. These constituents, particularly lignin, bear polar functional groups, such as alcohols, aldehydes, ketones, acids, phenolic hydroxides, and ethers, that can be involved in chemical bonding. Because of the polar nature of the material, its adsorption of dissolved solids such as transition metals and polar organic molecules is quite high. These properties have led to the use of peat as an agent for the purification of industrial wastewater.

Peat adsorption is a "polishing" process which can achieve very low effluent concentrations for several pollutants. If the concentrations of pollutants are above 10 mg/l, then peat adsorption must be preceded by pH adjustment for metals precipitation and subsequent clarification. Pretreatment is also required for chromium wastes using ferric chloride and sodium sulfide. The wastewater is then pumped into a large metal chamber called a kier which contains a layer of peat through which the waste stream passes. The water flows to a second kier for further adsorption. The wastewater is then ready for discharge. This system may be automated or manually operated.

Application and Performance. Peat adsorption can be used for removal of residual dissolved metals from clarifier effluent. Peat moss may be used to treat wastewaters containing heavy metals such as mercury, cadmium, zinc, copper, iron, nickel, chromium, and lead, as well as organic matter such as oil, detergents, and dyes. Peat adsorption is currently used commercially at a textile plant, a newsprint facility, and a metal reclamation operation.

Table VII-27 (page 234) contains performance figures obtained from pilot plant studies. Peat adsorption was preceded by pH adjustment for precipitation and by clarification.

In addition, pilot plant studies have shown that chelated metal wastes, as well as the chelating agents themselves, are removed by contact with peat moss.

Advantages and Limitations. The major advantages of the system include its ability to yield low pollutant concentrations, its broad scope in terms of the pollutants eliminated, and its capacity to accept wide variations of waste water composition.

Limitations include the cost of purchasing, storing, and disposing of the peat moss; the necessity for regular replacement of the peat may lead to high operation and maintenance costs. Also, the pH adjustment must be altered according to the composition of the waste stream.

Operational Factors. Reliability: The question of long term reliability is not yet fully answered. Although the manufacturer reports it to be a highly reliable system, operating experience is needed to verify the claim.

Maintainability: The peat moss used in this process soon exhausts its capacity to adsorb pollutants. At that time, the kiers must be opened, the peat removed, and fresh peat placed inside. Although this procedure is easily and quickly accomplished, it must be done at regular intervals, or the system's efficiency drops drastically.

Solid Waste Aspects: After removal from the kier, the spent peat must be eliminated. If incineration is used, precautions should be taken to insure that those pollutants removed from the water are not released again in the combustion process. Presence of sulfides in the spent peat, for example, will give rise to sulfur dioxide in the fumes from burning. The presence of significant quantities of toxic heavy metals in canmaking wastewater will in general preclude incineration of peat used in treating these wastes.

Demonstration Status. Only three facilities currently use commercial adsorption systems in the United States - a textile manufacturer, a newsprint facility, and a metal reclamation firm.

23. Reverse Osmosis

The process of osmosis involves the passage of a liquid through a semipermeable membrane from a dilute to a more concentrated solution. Reverse osmosis (RO) is an operation in which pressure is applied to the more concentrated solution, forcing the permeate to diffuse through the membrane and into the more dilute solution. This filtering action produces a concentrate and a permeate on opposite sides of the membrane. The concentrate can then be further treated or returned to the original operation for continued use, while the permeate water can be recycled for use as clean water. Figure VII-26 (page 262) depicts a reverse osmosis system.

As illustrated in Figure VII-27 (page 263), there are three basic configurations used in commercially available RO modules: tubular, spiral-wound, and hollow fiber. All of these operate on the principle described above, the major difference being their mechanical and structural design characteristics.

The tubular membrane module uses a porous tube with a cellulose acetate membrane-lining. A common tubular module consists of a length of 2.5 cm (1 inch) diameter tube wound on a supporting spool and encased in a plastic shroud. Feed water is driven into the tube under pressures varying from 40 - 55 atm (600-800 psi). The permeate passes through the walls of the tube and is collected in a manifold while the concentrate is drained off at the end of the tube. A less widely used tubular RO module uses a straight tube contained in a housing, under the same operating conditions.

Spiral-wound membranes consist of a porous backing sandwiched between two cellulose acetate membrane sheets and bonded along three edges. The fourth edge of the composite sheet is attached to a large permeate collector tube. A spacer screen is then placed on top of the membrane sandwich and the entire stack is rolled around the centrally located tubular permeate collector. The rolled up package is inserted into a pipe able to withstand the high operating pressures employed in this process, up to 55 atm (800 psi) with the spiral-wound module. When the system is operating, the pressurized product water permeates the membrane and flows through the backing material to the central collector tube. The concentrate is drained off at the end of the container pipe and can be reprocessed or sent to further treatment facilities.

The hollow fiber membrane configuration is made up of a bundle of polyamide fibers of approximately 0.0075 cm (0.003 in.) outside diameter and 0.0043 cm (0.0017 in.) inside diameter. A commonly used hollow fiber module contains several hundred thousand of the fibers placed in a long tube, wrapped around a flow screen, and rolled into a spiral. The fibers are bent in a U-shape and their ends are supported by an epoxy bond. The hollow fiber unit is operated under 27 atm (400 psi), the feed water being dispersed from the center of the module through a porous distributor tube. Permeate flows through the membrane to the hollow interiors of the fibers and is collected at the ends of the fibers.

The hollow fiber and spiral-wound modules have a distinct advantage over the tubular system in that they are able to load a very large membrane surface area into a relatively small volume. However, these two membrane types are much more susceptible to fouling than the tubular system, which has a larger flow channel. This characteristic also makes the tubular membrane much easier to clean and regenerate than either the spiral-wound or hollow fiber modules. One manufacturer claims that their helical tubular module can be physically wiped clean by passing a soft porous polyurethane plug under pressure through the module.

Application and Performance. In a number of metal processing plants, the overflow from the first rinse in a countercurrent setup is directed to a reverse osmosis unit, where it is separated into two streams. The concentrated stream contains dragged out chemicals and is returned to the bath to replace the loss of solution due to evaporation and dragout. The dilute stream (the permeate) is routed to the last rinse tank to provide water for the rinsing operation. The rinse flows from the last tank to the first tank and the cycle is complete.

The closed-loop system described above may be supplemented by the addition of a vacuum evaporator after the RO unit in order to further reduce the volume of reverse osmosis concentrate. The evaporated vapor can be condensed and returned to the last rinse tank or sent on for further treatment.

The largest application has been for the recovery of nickel solutions. It has been shown that RO can generally be applied to most acid metal baths with a high degree of performance, providing that the membrane unit is not overtaxed. The limitations most critical here are the allowable pH range and maximum operating pressure for each particular configuration. Adequate prefiltration is also essential. Only three membrane types are readily available in commercial RO units, and their overwhelming use has been for the recovery of various acid metal baths. For the purpose of calculating performance predictions of this technology, a rejection ratio of 98 percent is assumed for dissolved salts, with 95 percent permeate recovery.

Advantages and Limitations. The major advantage of reverse osmosis for handling process effluents is its ability to concentrate dilute solutions for recovery of salts and chemicals with low power requirements. No latent heat of vaporization or fusion is required for effecting separations; the main energy requirement is for a high pressure pump. It requires relatively little floor space for compact, high capacity units, and it exhibits good recovery and rejection rates for a number of typical process solutions. A limitation of the reverse osmosis process for treatment of process effluents is its limited temperature range for satisfactory operation. For cellulose acetate systems, the preferred limits are 18° to 30°C (65° to 85°F); higher temperatures will increase the rate of membrane hydrolysis and reduce system life, while lower temperatures will result in decreased fluxes with no damage to the membrane. Another limitation is inability to handle certain solutions.

Strong oxidizing agents, strongly acidic or basic solutions, solvents, and other organic compounds can cause dissolution of the membrane. Poor rejection of some compounds such as borates and low molecular weight organics is another problem. Fouling of membranes by slightly soluble components in solution or colloids has caused failures, and fouling of membranes by feed waters with high levels of suspended solids can be a problem. A final limitation is inability to treat or achieve high concentration with some solutions. Some concentrated solutions may have initial osmotic pressures which are so high that they either exceed available operating pressures or are uneconomical to treat.

Operational Factors. Reliability: Very good reliability is achieved so long as the proper precautions are taken to minimize the chances of fouling or degrading the membrane. Sufficient testing of the waste stream prior to application of an RO system will provide the information needed to insure a successful application.

Maintainability: Membrane life is estimated to range from six months to three years, depending on the use of the system. Down time for flushing or cleaning is on the order of 2 hours as often as once each week; a substantial portion of maintenance time must be spent on cleaning any prefilters installed ahead of the reverse osmosis unit.

Solid Waste Aspects: In a closed loop system utilizing RO there is a constant recycle of concentrate and a minimal amount of solid waste. Prefiltration eliminates many solids before they reach the module and helps keep the buildup to a minimum. These solids require proper disposal.

Demonstration Status. There are presently at least one hundred reverse osmosis waste water applications in a variety of industries. In addition to these, there are thirty to forty units being used to provide pure process water for several industries. Despite the many types and configurations of membranes, only the spiral-wound cellulose acetate membrane has had widespread success in commercial applications. One canmaking plant has reverse osmosis equipment in-place.

24. Sludge Bed Drying

As a waste treatment procedure, sludge bed drying is employed to reduce the water content of a variety of sludges to the point where they are amenable to mechanical collection and removal to landfill. These beds usually consist of 15 to 45 cm (6 to 18 in.) of sand over a 30 cm (12 in.) deep gravel drain system made up of 3 to 6 mm (1/8 to 1/4 in.) graded gravel overlying drain

Its disadvantages are the large area of land required and long drying times that depend, to a great extent, on climate and weather.

Operational Factors. Reliability: Reliability is high with favorable climactic conditions, proper bed design and care to avoid excessive or unequal sludge application. If climatic conditions in a given area are not favorable for adequate drying, a cover may be necessary.

Maintainability: Maintenance consists basically of periodic removal of the dried sludge. Sand removed from the drying bed with the sludge must be replaced and the sand layer resurfaced.

The resurfacing of sludge beds is the major expense item in sludge bed maintenance, but there are other areas which may require attention. Underdrains occasionally become clogged and have to be cleaned. Valves or sludge gates that control the flow of sludge to the beds must be kept watertight. Provision for drainage of lines in winter should be provided to prevent damage from freezing. The partitions between beds should be tight so that sludge will not flow from one compartment to another. The outer walls or banks around the beds should also be watertight.

Solid Waste Aspects: The full sludge drying bed must either be abandoned or the collected solids must be removed to a landfill. These solids contain whatever metals or other materials were settled in the clarifier. Metals will be present as hydroxides, oxides, sulfides, or other salts. They have the potential for leaching and contaminating ground water, whatever the location of the semidried solids. Thus the abandoned bed or landfill should include provision for runoff control and leachate monitoring.

Demonstration Status. Sludge beds have been in common use in both municipal and industrial facilities for many years. However, protection of ground water from contamination is not always adequate.

25. Ultrafiltration

Ultrafiltration (UF) is a process which uses semipermeable polymeric membranes to separate emulsified or colloidal materials suspended in a liquid phase by pressurizing the liquid so that it permeates the membrane. The membrane of an ultrafilter forms a molecular screen which retains molecular particles based on their differences in size, shape, and chemical structure. The membrane permits passage of solvents and lower molecular weight molecules. At present, an ultrafilter is capable of removing materials with molecular weights in the range of 1,000 to 100,000 and particles of comparable or larger sizes.

In an ultrafiltration process, the feed solution is pumped through a tubular membrane unit. Water and some low molecular weight materials pass through the membrane under the applied pressure of 10 to 100 psig. Emulsified oil droplets and suspended particles are retained, concentrated, and removed continuously. In contrast to ordinary filtration, retained materials are washed off the membrane filter rather than held by it. Figure VII-29 (page 265) represents the ultrafiltration process.

Application and Performance. Ultrafiltration has potential application to canmaking plants for separation of oils and residual solids from a variety of waste streams. In treating canmaking wastewater its greatest applicability would be as a polishing treatment to remove residual precipitated metals after chemical precipitation and clarification. Successful commercial use, however, has been primarily for separation of emulsified oils from wastewater. Hundreds of such units now operate in the United States, treating emulsified oils from a variety of industrial processes. Capacities of currently operating units range from a few hundred gallons a week to 50,000 gallons per day. Concentration of oily emulsions to 60 percent oil or more are possible. Oil concentrates of 40 percent or more are generally suitable for incineration, and the permeate can be treated further and in some cases recycled back to the process. In this way, it is possible to eliminate contractor removal costs for oil from some oily waste streams.

Table VII-28 (page 234) indicates ultrafiltration performance (note that UF is not intended to remove dissolved solids). The removal percentages shown are typical, but they can be influenced by pH and other conditions. The high TSS level is unusual for this technology and ultrafiltration is assumed to reduce the TSS level by one-third after mixed media filtration.

The permeate or effluent from the ultrafiltration unit is frequently of a quality that can be reused in industrial applications or discharged directly. The concentrate or brine from the ultrafiltration unit can be disposed of as any oily or solid waste.

Advantages and Limitations. Ultrafiltration is sometimes an attractive alternative to chemical treatment because of lower capital equipment, installation, and operating costs, when treating very high concentrations of oil or where suspended solids removal to a very low concentration is required. It places a positive barrier between pollutants and effluent which reduces the possibility of extensive pollutant discharge due to operator error or upset as may sometimes occur in settling and skimming systems. Alkaline values in alkaline cleaning solutions can be recovered and reused in process.

A limitation of ultrafiltration for treatment of process effluents is its narrow temperature range (18° to 30°C) for satisfactory operation. Membrane life decreases with higher temperatures, but flux increases at elevated temperatures. Therefore, surface area requirements are a function of temperature and become a tradeoff between initial costs and replacement costs for the membrane. In addition, ultrafiltration cannot handle certain solutions. Strong oxidizing agents, solvents, and other organic compounds can dissolve the membrane. Fouling is sometimes a problem, although the high velocity of the wastewater normally creates enough turbulence to keep fouling at a minimum. Large solids particles can sometimes puncture the membrane and must be removed by gravity settling or filtration prior to the ultrafiltration unit.

Operational Factors. Reliability: The reliability of an ultrafiltration system is dependent on the proper filtration, settling or other treatment of incoming waste streams to prevent damage to the membrane. Careful pilot studies should be done in each instance to determine necessary pretreatment steps and the exact membrane type to be used.

Maintainability: A limited amount of regular maintenance is required for the pumping system. In addition, membranes must be periodically changed. Maintenance associated with membrane plugging can be reduced by selection of a membrane with optimum physical characteristics and sufficient velocity of the waste stream. It is often necessary to occasionally pass a detergent solution through the system to remove an oil and grease film which accumulates on the membrane. With proper maintenance membrane life can be greater than twelve months.

Solid Waste Aspects: Ultrafiltration is used primarily to recover solids and liquids. It therefore eliminates solid waste problems when the solids (e.g., paint solids) can be recycled to the process. Otherwise, the stream containing solids must be treated by end-of-pipe treatment. In the most probable applications within the coil coating category, the ultrafilter would remove hydroxides or sulfides of metals which have recovery value.

Demonstration Status. The ultrafiltration process is well developed and commercially available for treatment of wastewater or recovery of certain high molecular weight liquid and solid contaminants. One canmaking plant has ultrafiltration equipment in-place treating the entire plant wastewater flow and three or more have ultrafiltration as a pretreatment for small volume high oil waste streams.

26. Vacuum Filtration

In wastewater treatment plants, sludge dewatering by vacuum filtration generally uses cylindrical drum filters. These drums have a filter medium which may be cloth made of natural or synthetic fibers or a wire-mesh fabric. The drum is suspended above and dips into a vat of sludge. As the drum rotates slowly, part of its circumference is subject to an internal vacuum that draws sludge to the filter medium. Water is drawn through the porous filter cake to a discharge port, and the dewatered sludge, loosened by compressed air, is scraped from the filter mesh. Because the dewatering of sludge on vacuum filters is relativley expensive per kilogram of water removed, the liquid sludge is frequently thickened prior to processing. A vacuum filter is shown in Figure VII-30 (page 266).

Application and Performance. Vacuum filters are frequently used both in municipal treatment plants and in a wide variety of industries. They are most commonly used in larger facilities, which may have a thickener to double the solids content of clarifier sludge before vacuum filtering.

The function of vacuum filtration is to reduce the water content of sludge, so that the solids content increases from about 5 percent to about 30 percent.

Advantages and Limitations. Although the initial cost and area requirement of the vacuum filtration system are higher than those of a centrifuge, the operating cost is lower, and no special provisions for sound and vibration protection need be made. The dewatered sludge from this process is in the form of a moist cake and can be conveniently handled.

Operational Factors. Reliability: Vacuum filter systems have proven reliable at many industrial and municipal treatment facilities. At present, the largest municipal installation is at the West Southwest wastewater treatment plant of Chicago, Illinois, where 96 large filters were installed in 1925, functioned approximately 25 years, and then were replaced with larger units. Original vacuum filters at Minneapolis-St. Paul, Minnesota now have over 28 years of continuous service, and Chicago has some units with similar or greater service life.

Maintainability: Maintenance consists of the cleaning or replacement of the filter media, drainage grids, drainage piping, filter pans, and other parts of the equipment. Experience in a number of vacuum filter plants indicates that maintenance consumes approximately 5 to 15 percent of the total time. If carbonate buildup or other problems are unusually severe, maintenance time may be as high as 20 percent. For this reason, it is desirable to maintain one or more spare units.

Demonstration Status. Vacuum filtration has been widely used for many years. It is a fully proven, conventional technology for sludge dewatering.

IN-PLANT TECHNOLOGIES

The intent of in-plant technology for the canmaking subcategory is to reduce or eliminate the waterborne waste loads which require end-of-pipe treatment and thereby improve the overall effectiveness of an existing wastewater treatment system or reduce the requirements of a new treatment system. In-plant technology involves optimum machine configuration and operating conditions along with improved rinsing and water conservation practices.

The reduction of the volume of wastewater which must be discharged from a canmaking facility is of highest importance to reducing the total discharge of pollutants from the facility. Because the model treatment produces a constant concentration of pollutants in the effluent, a major part of the pollutant discharge reduction required in this subcategory is achieved by reduction of the volume of water discharged.

Canwasher Configuration

The configuration of a canwasher and the conditions under which it is operated may have a substantial impact on a plant's ability to reduce wastewater flow to meet discharge requirements. The factors discussed in the following paragraphs may have substantial impact in this area and should be considered in any effort or program to reduce wastewater generation and discharge. Taken together, these internal water reuse practices can eliminate the introduction of new water into the canwasher at any point except as feed water to the stage 5 rinse.

The basic configuration of a canwasher is established when it is constructed or during a major modification. The classic configuration is shown in Figure III-6 (page 29) although almost all canwashers have some modifications to this basic configuration made during or after installation. The arrangement of rinse tanks, nozzles and flow is of primary importance. Minor modifications and additions can be made to existing equipment to improve operations.

Introduction of water in the last riser of a stage (shown in Figure III-4, page 27) can substantially reduce the water required to achieve a given level of can cleanliness. This technique applies the cleanest water to the can after it has been washed with less clean water. This process has some similarities to countercurrent cascade rinsing and is estimated to be about one-half as efficient resulting in a water use turn down ratio of about 4.

The number, type and location of spray nozzles and risers is an important consideration in canwasher effectiveness. Equilibrium between the concentration of pollutants on the can surface and the water in the recirculation sumps must be approached to attain effective rinsing with a minimum of water use.

Oil removal (shown in Figure III-8, page 31) from the system is desirable to promote the effectiveness of each succeeding stage of the canwasher. A preliminary - or vesitbule - rinse as the can enters the washer removes a substantial amount of oil in a form that it may be recovered for reuse in bodymaker fluid. Oil removal by skimming in a discharge or recirculation sump at each stage can also remove oil from the system.

Recovery and reuse of oil from the bodymaker sumps and some canwasher discharge points is sometimes feasible. This possibility should not be overlooked both from the stand point of reduced wastewater flow and the economics of oil use.

The internal reuse of water within the canwasher is the most commonly practiced method of reducing water use and wastewater discharge in canmaking. There are many ways in which water can be reused in a canwasher.

Counterflow rinsing, (depicted in Figure III-7, page 30) for the purpose of this document has been defined as the use of water from the stage 5 rinse in the stage 3 rinse with no other water used in the stage 3 rinse. This can completely eliminate the requirement for new water at the stage 3 rinse.

In some cases, there may be a pH barrier to the reuse of water from stage 5 to 3. This can be easily overcome by acidifying the water between stage 5 and stage 3.

Water reuse at stage 1 uses wastewater from stage 3 for all of the water requirement for this stage.

A vestibule rinse or prerinse added before the entrance to stage 1 can provide some advantage by reducing the amount of oil to be removed later in the canwasher. Water for this prerinse may be drawn from the stage 3 discharge. The heavy oil removed from the can may usually be recovered for reuse in bodymaker fluid.

Solution makeup water. This water may be drawn from the stage 5 rinse discharge and used as a feed into stage 4 and stage 2 to maintain a proper fluid level and provide a slight overflow for removal of oil and dissolved salt in each of these stages. Even though they are small, these flows contribute to pollutant discharge.

Treated process wastewater may be regulated and used as part of the canwasher or water supply is a demonstrated mechanism for reducing the total volume of water which must be discharged from the canmaking operation. Because the wastewater treatment recovers much of the pollutant introduced in the canwasher it can constitute a major fraction of the water flow to the canwasher. At least two plants in the subcategory use this water conservation practice.

Countercurrent Cascade Rinsing

The use of countercurrent cascade rinsing is a form of canwasher configuration that warrants separate discussion because of the possible efficiency of water use. Rinse water requirements and the benefits of countercurrent rinsing may be influenced by the volume of solution dragout carried into each rinse stage by the material being rinsed, by the number of rinse stages used, by the initial concentrations of impurities being removed, and by the final product cleanliness required (See Figures III-3, 4 and 5, pages 26-28). Two cases are considered: first is the application of countercurrent cascade rinsing to a simple water circuit canwasher and the application to a more complicated circuit in which the new water is introduced into the last riser of the rinse stage. The influence of these factors is expressed in the rinsing equation which is stated simply below:

A. Simple Water Circuit Canwasher

V_r is the flow through each rinse stage.

C_o is the concentration of the contaminant(s) in the initial process bath

C_f is the concentration of the contaminant(s) in the final rinse to give acceptable product cleanliness.

n is the number of rinse stages employed
and

V_d is the drag-out carried into each rinse stage, expressed as a flow.

For convenience we can set $r = C_o/C_f$ because for any calculation about flow reduction, the cleanliness ratio C_o/C_f is maintained as a constant.. For a multi-stage rinse, the total volume of rinse wastewater is equal to n times V_r, while for a countercurrent rinse the total volume of wastewater discharge equals V_r.

Drag-out is solution which remains on the surface of material when it is removed from process baths or rinses.

The potential flow reduction possible with countercurrent cascade rinse is illustrated by the following analysis. To calculate the cleanliness ratio, r, we start with an assumed water use of 215 l/1000 cans (the median plant water use of plants in the data base) and subtract a 10 percent allowance for wastewater generated from oil sump discharge, ion exchange regeneration, fume scrubber discharge, and batch dumps of process tanks (i.e. acid cleaner and conversion coating solution). Thus, 215 - 21.5 = 193.5 l/1000 cans represents the rinse water use for single stage rinses.

Without specific data available to determine drag-out we can assume a dragout film thickness of 0.075 mm (2.9 mils) which is equivalent to a poorly drained vertical surface film thickness; and a surface area of 555 sq. cm for a standard 12-ounce can body (can diameter is 6.5 cm and can height is 12.0 cm). The volume of dragout or carryover is:

V_d = 555 sq cm/can x .0075 cm = 4.16 cu cm/can (ml/can) or 4.16 l/1000 cans

Given the configuration of the inverted seamless can body as it passes through the washer with a dished impression in the bottom, 4.16 ml per can carryover from one stage to the next by an inverted can which has little time to drain, seems reasonable especially when an air knife is used. Substituting in the rinsing equation for a single stage rinse, $V_r = r \times V_d$, and solving for r, we get

$$r = \frac{193.5}{4.16} = 46.51$$

If a two stage countercurrent cascade rinse is substituted for the single stage rinse, we get the following rinse water volume:

$$\begin{aligned} V_r &= (46.51)^{1/2}\,(4.16) \\ &= 6.82 \times 4.16 \\ &= 28.4 \text{ l/1000 cans} \end{aligned}$$

If a three stage countercurrent cascade rinse is substituted for the single stage rinse, we get for a rinse water volume:

$$\begin{aligned} V_r &= (46.51)^{1/3}(4.16) \\ &= 3.59 \times 4.16 \\ &= 15.0 \text{ l/1000 cans} \end{aligned}$$

Similarly, the introduction of new water to the rinse at the first riser will reduce the water required to achieve the constant cleanliness ratio to 48.4 l/1000 cans. Addition of first riser introduction of water to the first cascade of a 2 stage countercurrent cascade rinse will reduce the water requirement to 9.4 l/1000 cans.

The application of countercurrent cascade rinse technology in the DI rinse should also be considered. This would provide an additional process station where surface contaminates can be removed from the can surface and provide added insurance of can cleanliness.

Equipment Maintenance

A canwasher is a unified sequence of process operations which must be operationally coordinated to function optimally. Even small maintenance omissions or failures can have a substantial impact on water use and pollutant discharge. The failure or reduced effectiveness of many functions may be compensated by increasing the water flow and compensating the fault in can rinsing rather than correcting the problem. Some examples are:

- The failure of an air knife because of plugged jets, low air pressure or other failure allows additional carryover of pollutants into the stages that follow the failed air knife.
- The failure or decreased efficiency of a belt wiper between stages can increase drag out into the following stages.
- Decreased efficiency of circulating pumps can reduce the rinsing effectiveness of rinse stages.
- Cleaning and replacement of spray nozzles to ensure proper effectiveness.

In-process Control

The conversion coating function is a key step of the canmaking operation. This is one of the steps in which material is added to the can. The two principal types of conversion coating used on cans are chromating and phosphating.

A number of parameters require monitoring and control to maximize coating formation rate and minimize the amount of material discarded.

All types of conversion coating operations require careful monitoring and control of pH. If the pH is not kept at the optimum level, either the chemical reaction proceeds too slowly or the surface of the can is excessively etched. The pH of the system can be sensed electronically and automatic make-up of specific chemicals performed in accordance with manufacturers' specifications. Chemical suppliers provide a series of chemicals for each type of conversion coating. The series includes a new bath formulation and one or two replenishment chemicals depending upon the constituent that has been depleted. This system maximizes use of all chemicals and provides for a continued high quality product.

Conversion coating temperature must be constantly monitored and kept within an acceptable range. Low temperatures may slow film formation and excessively high temperatures will degrade the freshly formed film. For a given line speed, there should be adequate spray nozzle coverage and pressure. This assures that all areas of each can have sufficient reaction time to allow buildup of a specified film thickness.

The chemicals used in chromate conversion coatings contain significant quantities of hexavalent chromium. The hexavalent chromium eventually becomes reduced to the trivalent state, precluding its use as part of the film. Certain chromate conversion coating systems are designed to regenerate chromium. These systems pump the chromate conversion coating solution out of the process tank to another tank where it is electrolytically regenerated. This application of electrical current to the solution increases the valence of the trivalent chromium to hexavalent chromium. The solution is then returned to the process tank.

In-Process Substitutions

The in-process substitutions for this subcategory involve only the conversion coating phases of the total operation. The cleaning, rinsing, and painting remain virtually unchanged. These in-process substitutions eliminate the discharge of a significant pollutant from the conversion coating operation.

Certain chromating solutions contain cyanide ions to promote faster reaction of the solution. Cyanide is a priority pollutant which requires separate treatment to remove it once it is in solution. Chromating conversion coatings are no longer widely used in the canmaking subcategory, although it continues to be used in some plants. Where chromating systems are used chemical formulations which do not contain cyanide are available and efforts should be made to eliminate cyanide use where possible.

TABLE VII-1
pH CONTROL EFFECT ON METALS REMOVAL

	Day 1		Day 2		Day 3	
	In	Out	In	Out	In	Out
pH Range	2.4-3.4	8.5-8.7	1.0-3.0	5.0-6.0	2.0-5.0	6.5-8.1
(mg/l)						
TSS	39	8	16	19	16	7
Copper	312	0.22	120	5.12	107	0.66
Zinc	250	0.31	32.5	25.0	43.8	0.66

TABLE VII-2

EFFECTIVENESS OF SODIUM HYDROXIDE FOR METALS REMOVAL

	Day 1		Day 2		Day 3	
	In	Out	In	Out	In	Out
pH Range (mg/l)	2.1-2.9	9.0-9.3	2.0-2.4	8.7-9.1	2.0-2.4	8.6-9.1
Cr	0.097	0.0	0.057	0.005	0.068	0.005
Cu	0.063	0.018	0.078	0.014	0.053	0.019
Fe	9.24	0.76	15.5	0.92	9.41	0.95
Pb	1.0	0.11	1.36	0.13	1.45	0.11
Mn	0.11	0.06	0.12	0.044	0.11	0.044
Ni	0.077	0.011	0.036	0.009	0.069	0.011
Zn	.054	0.0	0.12	0.0	0.19	0.037
TSS		13		11		11

TABLE VII-3
EFFECTIVENESS OF LIME AND SODIUM HYDROXIDE FOR METALS REMOVAL

	Day 1		Day 2		Day 3	
	In	Out	In	Out	In	Out
pH Range (mg/l)	9.2-9.6	8.3-9.8	9.2	7.6-8.1	9.6	7.8-8.2
Al	37.3	0.35	38.1	0.35	29.9	0.35
Co	3.92	0.0	4.65	0.0	4.37	0.0
Cu	0.65	0.003	0.63	0.003	0.72	0.003
Fe	137	0.49	110	0.57	208	0.58
Mn	175	0.12	205	0.012	245	0.12
Ni	6.86	0.0	5.84	0.0	5.63	0.0
Se	28.6	0.0	30.2	0.0	27.4	0.0
Ti	143	0.0	125	0.0	115	0.0
Zn	18.5	0.027	16.2	0.044	17.0	0.01
TSS	4390	9	3595	13	2805	13

TABLE VII-4

THEORETICAL SOLUBILITIES OF HYDROXIDES AND SULFIDES OF SELECTED METALS IN PURE WATER

Metal	Solubility of metal ion, mg/l		
	As Hydroxide	As Carbonate	As Sulfide
Cadmium (Cd^{++})	2.3×10^{-5}	1.0×10^{-4}	6.7×10^{-10}
Chromium (Cr^{+++})	8.4×10^{-4}		No precipitate
Cobalt (Co^{++})	2.2×10^{-1}		1.0×10^{-8}
Copper (Cu^{++})	2.2×10^{-2}		5.8×10^{-18}
Iron (Fe^{++})	8.9×10^{-1}		3.4×10^{-5}
Lead (Pb^{++})	2.1	7.0×10^{-3}	3.8×10^{-9}
Manganese (Mn^{++})	1.2		2.1×10^{-3}
Mercury (Hg^{++})	3.9×10^{-4}	3.9×10^{-2}	9.0×10^{-20}
Nickel (Ni^{++})	6.9×10^{-3}	1.9×10^{-1}	6.9×10^{-8}
Silver (Ag^{+})	13.3	2.1×10^{-1}	7.4×10^{-12}
Tin (Sn^{++})	1.1×10^{-4}		3.8×10^{-8}
Zinc (Zn^{++})	1.1	7.0×10^{-4}	2.3×10^{-7}

TABLE VII-5

SAMPLING DATA FROM SULFIDE PRECIPITATION-SEDIMENTATION SYSTEMS

Treatment	Lime, FeS, Poly-electrolyte, Settle, Filter		Lime, FeS, Poly-electrolyte, Settle, Filter		NaOH, Ferric Chloride, Na_2S Clarify (1 stage)	
	In	Out	In	Out	In	Out
pH	5.0-6.8	8-9	7.7	7.38		
(mg/l)						
Cr^{+6}	25.6	<0.014	0.022	<0.020	11.45	<.005
Cr	32.3	<0.04	2.4	<0.1	18.35	<.005
Cu	-	-	-	-	0.029	0.003
Fe	0.52	0.10	108	0.6	-	-
Ni	-	-	0.68	<0.1	-	-
Zn	39.5	<0.07	33.9	<0.1	0.060	0.009

These data were obtained from three sources:

Summary Report, Control and Treatment Technology for the Metal Finishing Industry: Sulfide Precipitation, USEPA, EPA No. 625/8/80-003, 1979.

Industrial Finishing, Vol. 35, No. 11, November, 1979.

Electroplating sampling data from plant 27045.

TABLE VII-6

SULFIDE PRECIPITATION-SEDIMENTATION PERFORMANCE

Parameter	Treated Effluent (mg/l)
Cd	0.01
Cr (T)	0.05
Cu	0.05
Pb	0.01
Hg	0.03
Ni	0.05
Ag	0.05
Zn	0.01

Table VII-6 is based on two reports:

Summary Report, Control and Treatment Technology for the Metal Finishing Industry: Sulfide Precipitation, USEPA, EPA No. 625/8/80-003, 1979.

Addendum to Development Document for Effluent Limitations Guidelines and New Source Performance Standards, Major Inorganic Products Segment of Inorganics Point Source Category, USEPA., EPA Contract No. EPA-68-01-3281 (Task 7), June, 1978.

Table VII-7

FERRITE CO-PRECIPITATION PERFORMANCE

Metal	Influent(mg/l)	Effluent(mg/l)
Mercury	7.4	0.001
Cadmium	240	0.008
Copper	10	0.010
Zinc	18	0.016
Chromium	10	<0.010
Manganese	12	0.007
Nickel	1,000	0.200
Iron	600	0.06
Bismuth	240	0.100
Lead	475	0.010

NOTE: These data are from:
Sources and Treatment of Wastewater in the Nonferrous Metals Industry, USEPA, EPA No. 600/2-80-074, 1980.

TABLE VII-8

CONCENTRATION OF TOTAL CYANIDE (mg/l)

Plant	Method	In	Out
1057	$FeSO_4$	2.57	0.024
		2.42	0.015
		3.28	0.032
33056	$FeSO_4$	0.14	0.09
		0.16	0.09
12052	$ZnSO_4$	0.46	0.14
		0.12	0.06
Mean			0.07

Table VII-9

MULTIMEDIA FILTER PERFORMANCE

Plant ID #	TSS Effluent Concentration, mg/l
06097	0.0, 0.0, 0.5
13924	1.8, 2.2, 5.6, 4.0, 4.0, 3.0, 2.2, 2.8 3.0, 2.0, 5.6, 3.6, 2.4, 3.4
18538	1.0
30172	1.4, 7.0, 1.0
36048	2.1, 2.6, 1.5
mean	2.61

TABLE VII-10
PERFORMANCE OF SELECTED SETTLING SYSTEMS

PLANT ID	SETTLING DEVICE	SUSPENDED SOLIDS CONCENTRATION (mg/l)					
		Day 1		Day 2		Day 3	
		In	Out	In	Out	In	Out
01057	Lagoon	54	6	56	6	50	5
09025	Clarifier Settling Ponds	1100	9	1900	12	1620	5
11058	Clarifier	451	17	-	-	-	-
12075	Settling Pond	284	6	242	10	502	14
19019	Settling Tank	170	1	50	1	-	-
33617	Clarifier & Lagoon	-	-	1662	16	1298	4
40063	Clarifier	4390	9	3595	12	2805	13
44062	Clarifier	182	13	118	14	174	23
46050	Settling Tank	295	10	42	10	153	8

Table VII-11

SKIMMING PERFORMANCE

		Oil & Grease mg/l	
Plant	Skimmer Type	In	Out
06058	API	224,669	17.9
06058	Belt	19.4	8.3

TABLE VII-12

SELECTED PARITION COEFFICIENTS

Priority Pollutant		Log Octanol/Water Partition Coefficient
1	Acenaphthene	4.33
11	1,1,1-Trichloroethane	2.17
13	1,1-Dichloroethane	1.79
15	1,1,2,2-Tetrachloroethane	2.56
18	Bis(2-chloroethyl)ether	1.58
23	Chloroform	1.97
29	1,1-Dichloroethylene	1.48
39	Fluoranthene	5.33
44	Methylene chloride	1.25
64	Pentachlorophenol	5.01
66	Bis(2-ethylhexyl) phthalate	8.73
67	Butyl benzyl phthalate	5.80
68	Di-n butyl phthalate	5.20
72	Benzo(a)anthracene	5.61
73	Benzo(a)pyrene	6.04
74	3,4-benzofluoranthene	6.57
75	Benzo(k)fluoranthene	6.84
76	Chrysene	5.61
77	Acenaphthylene	4.07
78	Anthracene	4.45
79	Benzo(ghi)perylene	7.23
80	Fluorene	4.18
81	Phenanthrene	4.46
82	Dibenzo(a,h)anthracene	5.97
83	Indeno(1,2,3,cd)pyrene	7.66
84	Pyrene	5.32
85	Tetrachloroethylene	2.88
86	Toluene	2.69

TABLE VII-13

TRACE ORGANIC REMOVAL BY SKIMMING API SEPARATOR PLUS BELT SKIMMERS

(From Plant 06058)

	Inf. mg/l	Eff. mg/l
Oil & Grease	225,000	14.6
Chloroform	0.023	0.007
Methylene Chloride	0.013	0.012
Naphthalene	2.31	0.004
N-nitrosodiphenylamine	59.0	0.182
Bis-2-ethylhexyl phthalate	11.0	0.027
Diethyl phthalate	-	-
Butylbenzyl phthalate	0.005	0.002
Di-n-octyl phthalate	0.019	0.002
Anthracene - phenanthrene	16.4	0.014
Toluene	0.02	0.012

Table VII-14

COMBINED METALS DATA EFFLUENT VALUES (mg/l)

	Mean	One Day Max.	10 Day Avg. Max.	30 Day Avg. Max.
Cd	0.079	0.32	0.15	0.13
Cr	0.08	0.42	0.17	0.12
Cu	0.58	1.90	1.00	0.73
Pb	0.12	0.15	0.13	0.12
Ni	0.57	1.41	1.00	0.75
Zn	0.30	1.33	0.56	0.41
Fe	0.41	1.23	0.63	0.51
Mn	0.21	0.43	0.34	0.27
TSS	12.0	41.0	20.0	15.5

TABLE VII-15
L&S PERFORMANCE
ADDITIONAL POLLUTANTS

Pollutant	Average Performance (mg/l)
Sb	0.7
As	0.51
Be	0.30
Hg	0.06
Se	0.30
Ag	0.10
Th	0.50
Al	1.11
Co	0.05
F	14.5

TABLE VII-16

COMBINED METALS DATA SET - UNTREATED WASTEWATER

Pollutant	Min. Conc (mg/l)	Max. Conc. (mg/l)
Cd	<0.1	3.83
Cr	<0.1	116
Cu	<0.1	108
Pb	<0.1	29.2
Ni	<0.1	27.5
Zn	<0.1	337.
Fe	<0.1	263
Mn	<0.1	5.98
TSS	4.6	4390

TABLE VII-17
MAXIMUM POLLUTANT LEVEL IN UNTREATED WASTEWATER

ADDITIONAL POLLUTANTS
(mg/l)

Pollutant	As & Se	Be	Ag	F
As	4.2	-	-	-
Be	-	10.24	-	-
Cd	<0.1	-	<0.1	<0.1
Cr	0.18	8.60	0.23	22.8
Cu	33.2	1.24	110.5	2.2
Pb	6.5	0.35	11.4	5.35
Ni	-	-	100	0.69
Ag	-	-	4.7	-
Zn	3.62	0.12	1512	<0.1
F	-	-	-	760
Fe	-	646	-	-
O&G	16.9	-	16	2.8
TSS	352	796	587.8	5.6

TABLE VII-18

PRECIPITATION-SETTLING-FILTRATION (LS&F) PERFORMANCE
Plant A

Parameters	No Pts.	Range mg/l	Mean ± std. dev.	Mean + 2 std. dev.
For 1979-Treated Wastewater				
Cr	47	0.015 - 0.13	0.045 ±0.029	0.10
Cu	12	0.01 - 0.03	0.019 ±0.006	0.03
Ni	47	0.08 - 0.64	0.22 ±0.13	0.48
Zn	47	0.08 - 0.53	0.17 ±0.09	0.35
Fe				
For 1978-Treated Wastewater				
Cr	47	0.01 - 0.07	0.06 ±0.10	0.26
Cu	28	0.005 - 0.055	0.016 ±0.010	0.04
Ni	47	0.10 - 0.92	0.20 ±0.14	0.48
Zn	47	0.08 - 2.35	0.23 ±0.34	0.91
Fe	21	0.26 - 1.1	0.49 ±0.18	0.85
Raw Waste				
Cr	5	32.0 - 72.0		
Cu	5	0.08 - 0.45		
Ni	5	1.65 - 20.0		
Zn	5	33.2 - 32.0		
Fe	5	10.0 - 95.0		

TABLE VII-19

PRECIPITATION-SETTLING-FILTRATION (LS&F) PERFORMANCE
Plant B

Parameters	No Pts.	Range mg/l	Mean ± std. dev.	Mean + 2 std. dev.
For 1979-Treated Wastewater				
Cr	175	0.0 - 0.40	0.068 ±0.075	0.22
Cu	176	0.0 - 0.22	0.024 ±0.021	0.07
Ni	175	0.01 - 1.49	0.219 ±0.234	0.69
Zn	175	0.01 - 0.66	0.054 ±0.064	0.18
Fe	174	0.01 - 2.40	0.303 ±0.398	1.10
TSS	2	1.00 - 1.00		
For 1978-Treated Wastewater				
Cr	144	0.0 - 0.70	0.059 ±0.088	0.24
Cu	143	0.0 - 0.23	0.017 ±0.020	0.06
Ni	143	0.0 - 1.03	0.147 ±0.142	0.43
Zn	131	0.0 - 0.24	0.037 ±0.034	0.11
Fe	144	0.0 - 1.76	0.200 ±0.223	0.47
Total 1974-1979-Treated Wastewater				
Cr	1288	0.0 - 0.56	0.038 ±0.055	0.15
Cu	1290	0.0 - 0.23	0.011 ±0.016	0.04
Ni	1287	0.0 - 1.88	0.184 ±0.211	0.60
Zn	1273	0.0 - 0.66	0.035 ±0.045	0.13
Fe	1287	0.0 - 3.15	0.402 ±0.509	1.42
Raw Waste				
Cr	3	2.80 - 9.15	5.90	
Cu	3	0.09 - 0.27	0.17	
Ni	3	1.61 - 4.89	3.33	
Zn	2	2.35 - 3.39		
Fe	3	3.13 -35.9	22.4	
TSS	2	177 -466.		

TABLE VII-20

PRECIPITATION-SETTLING-FILTRATION (LS&F) PERFORMANCE
Plant C

For Treated Wastewater

Parameters	No Pts.	Range mg/l	Mean ± std. dev.	Mean + 2 std. dev.
For Treated Wastewater				
Cd	103	0.010 - 0.500	0.049 ±0.049	0.147
Zn	103	0.039 - 0.899	0.290 ±0.131	0.552
TSS	103	0.100 - 5.00	1.244 ±1.043	3.33
pH	103	7.1 - 7.9	9.2*	
For Untreated Wastewater				
Cd	103	0.039 - 2.319	0.542 ±0.381	1.304
Zn	103	0.949 -29.8	11.009 ±6.933	24.956
Fe	3	0.107 - 0.46	0.255	
TSS	103	0.80 -19.6	5.616 ±2.896	11.408
pH	103	6.8 - 8.2	7.6*	

* pH value is median of 103 values.

TABLE VII-21

SUMMARY OF TREATMENT EFFECTIVENESS
(mg/l)

Pollutant Parameter	L&S Technology System				LS&F Technology System			
	Mean	One Day Max.	Ten Day Avg.	Thirty Day Avg.	Mean	One Day Max.	Ten Day Avg.	Thirty Day Avg.
114 Sb	0.70	2.87	1.28	1.14	0.47	1.93	0.86	0.76
115 As	0.51	2.09	0.86	0.83	0.34	1.39	0.57	0.55
117 Be	0.30	1.23	0.51	0.49	0.20	0.82	0.34	0.32
118 Cd	0.079	0.34	0.15	0.13	0.049	0.20	0.08	0.08
119 Cr	0.084	0.44	0.18	0.12	0.07	0.37	0.15	0.10
120 Cu	0.58	1.90	1.00	0.73	0.39	1.28	0.61	0.49
121 CN	0.07	0.29	0.12	0.11	0.047	0.20	0.08	0.08
122 Pb	0.12	0.42	0.20	0.16	0.08	0.28	0.13	0.11
123 Hg	0.06	0.25	0.10	0.10	0.036	0.15	0.06	0.06
124 Ni	0.74	1.92	1.27	1.00	0.22	0.55	0.37	0.29
125 Se	0.30	1.23	0.55	0.49	0.20	0.82	0.37	0.33
126 Ag	0.10	0.41	0.17	0.16	0.07	0.29	0.12	0.10
127 Tl	0.50	2.05	0.84	0.81	0.34	1.40	0.57	0.55
128 Zn	0.33	1.46	0.61	0.45	0.23	1.02	0.42	0.31
Al	2.24	6.43	3.20	2.52	1.49	6.11	2.71	2.41
Co	0.05	0.21	0.09	0.08	0.034	0.14	0.07	0.06
F	14.5	59.5	26.4	23.5		59.5	26.4	23.5
Fe	0.41	1.20	0.61	0.50	0.28	1.20	0.61	0.50
Mn	0.16	0.68	0.29	0.21	0.14	0.30	0.23	0.19
P	4.08	16.7	6.83	6.60	2.72	11.2	4.6	4.4
O&G		20.0	12.0	10.0		10.0	10.0	10.0
TSS	12.0	41.0	19.5	15.5	2.6	15.0	12.0	10.0

TABLE VII-22
TREATABILITY RATING OF PRIORITY POLLUTANTS UTILIZING CARBON ADSORPTION

Priority Pollutant	*Removal Rating	Priority Pollutant	*Removal Rating
1. acenaphthene	H	49. trichlorofluoromethane	M
2. acrolein	L	50. dichlorodifluoromethane	L
3. acrylonitrile	L	51. chlorodibromomethane	M
4. benzene	M	52. hexachlorobutadiene	H
5. benzidine	H	53. hexachlorocyclopentadiene	H
6. carbon tetrachloride (tetrachloromethane)	M	54. isophorone	H
7. chlorobenzene	H	55. naphthalene	H
8. 1,2,3-trichlorobenzene	H	56. nitrobenzene	H
9. hexachlorobenzene	H	57. 2-nitrophenol	H
10. 1,2-dichloroethane	M	58. 4-nitrophenol	H
11. 1,1,1-trichloroethane	M	59. 2,4-dinitrophenol	H
12. hexachloroethane	H	60. 4,6-dinitro-o-cresol	H
13. 1,1-dichloroethane	M	61. N-nitrosodimethylamine	M
14. 1,1,2-trichloroethane	M	62. N-nitrosodiphenylamine	H
15. 1,1,2,2-tetrachlorethane	H	63. N-nitrosodi-n-propylamine	M
16. chloroethane	L	64. pentachlorophenol	H
17. bis(chloromethyl) ether	-	65. phenol	M
18. bis(2-chloroethyl) ether	M	66. bis(2-ethylhexyl)phthalate	H
19. 2-chloroethylvinyl ether (mixed)	L	67. butyl benzyl phthalate	H
20. 2-chloronaphthalene	H	68. di-n-butyl phthalate	H
21. 2,4,6-trichlorophenol	H	69. di-n-octyl phthalate	H
22. parachlorometa cresol	H	70. diethyl phthalate	H
23. chloroform (trichloromethane)	L	71. dimethyl phthalate	H
24. 2-chlorophenol	H	72. 1,2-benzanthracene (benzo(a)anthracene)	H
25. 1,2-dichlorobenzene	H	73. benzo(a)pyrene (3,4-benzopyrene)	H
26. 1,3-dichlorobenzene	H	74. 3,4-benzofluoranthene (benzo(b)fluoranthene)	H
27. 1,4-dichlorobenzene	H	75. 11,12-benzofluoranthene (benzo(k)fluoranthene)	H
28. 3,3'-dichlorobenzidine	H	76. chrysene	H
29. 1,1-dichloroethylene	L	77. acenaphthylene	H
30. 1,2-trans-dichloroethylene	L	78. anthracene	H
31. 2,4-dichlorophenol	H	79. 1,12-benzoperylene (benzo (ghi)-perylene)	H
32. 1,2-dichloropropane	M	80. fluorene	H
33. 1,2-dichloropropylene (1,3-dichloropropene)	M	81. phenanthrene	H
34. 2,4-dimethylphenol	H	82. 1,2,3,6-dibenzanthracene (dibenzo(a,h) anthracene)	H
35. 2,4-dinitrotoluene	H	83. indeno (1,2,3-cd) pyrene (2,3-o-phenylene pyrene)	H
36. 2,6-dinitrotoluene	H	84. pyrene	-
37. 1,2-diphenylhydrazine	H	85. tetrachloroethylene	M
38. ethylbenzene	M	86. toluene	M
39. fluoranthene	H	87. trichloroethylene	L
40. 4-chlorophenyl phenyl ether	H	88. vinyl chloride (chloroethylene)	L
41. 4-bromophenyl phenyl ether	H	106. PCB-1242 (Aroclor 1242)	H
42. bis(2-chloroisopropyl)ether	M	107. PCB-1254 (Aroclor 1254)	H
43. bis(2-chloroethoxy)methane	M	108. PCB-1221 (Aroclor 1221)	H
44. methylene chloride (dichloromethane)	L	109. PCB-1332 (Aroclor 1232)	H
45. methyl chloride (chloromethane)	L	110. PCB-1248 (Aroclor 1248)	H
46. methyl bromide (bromomethane)	L	111. PCB-1260 (Aroclor 1260)	H
47. bromoform (tribromomethane)	H	112. PCB-1016 (Aroclor 1016)	H
48. dichlorobromomethane	M		

*Note Explanation of Removal Ratings

Category H (high removal)

adsorbs at levels ≥ 100 mg/g carbon at $C_f = 10$ mg/l

adsorbs at levels ≥ 100 mg/g carbon at $C_f < 1.0$ mg/l

Category M (moderate removal)

adsorbs at levels ≥ 100 mg/g carbon at $C_f = 10$ mg/l

adsorbs at levels ≤ 100 mg/g carbon at $C_f < 1.0$ mg/l

Category L (low removal)

adsorbs at levels < 100 mg/g carbon at $C_f = 10$ mg/l

adsorbs at levels < 10 mg/g carbon at $C_f < 1.0$ mg/l

C_f = final concentrations of priority pollutant at equilibrium

TABLE VII - 23

CLASSES OF ORGANIC COMPOUNDS ADSORBED ON CARBON

Organic Chemical Class	Examples of Chemical Class
Aromatic Hydrocarbons	benzene, toluene, xylene
Polynuclear Aromatics	naphthalene, anthracene biphenyls
Chlorinated Aromatics	chlorobenzene, polychlorinated biphenyls, aldrin, endrin, toxaphene, DDT
Phenolics	phenol, cresol, resorcenol and polyphenyls
Chorinated Phenolics	trichlorophenol, pentachlorophenol
*High Molecular Weight Aliphatic and Branch Chain hydrocarbons	gasoline, kerosine
Chlorinated Aliphatic hydrocarbons	carbon tetrachloride, perchloroethylene
*High Molecular Weight Aliphatic Acids and Aromatic Acids	tar acids, benzoic acid
*High Molecular Weight Aliphatic Amines and Aromatic Amines	aniline, toluene diamine
*High Molecular Weight Ketones, Esters, Ethers and Alcohols	hydroquinone, polyethylene glycol
Surfactants	alkyl benzene sulfonates
Soluble Organic Dyes	methylene blue, indigo carmine

---

* High Molecular Weight includes compounds in the broad range of from 4 to 20 carbon atoms

Table VII-24

ACTIVATED CARBON PERFORMANCE (MERCURY)

Plant	Mercury levels - mg/l In	 Out
A	28.0	0.9
B	0.36	0.015
C	0.008	0.0005

Table VII-25

ION EXCHANGE PERFORMANCE

Parameter	Plant A		Plant B	
All Values mg/l	Prior To Purification	After Purification	Prior To Purification	After Purification
Al	5.6	0.20	-	-
Cd	5.7	0.00	-	-
Cr+3	3.1	0.01	-	-
Cr+6	7.1	0.01	-	-
Cu	4.5	0.09	43.0	0.10
CN	9.8	0.04	3.40	0.09
Au	-	-	2.30	0.10
Fe	7.4	0.01	-	-
Pb	-	-	1.70	0.01
Mn	4.4	0.00	-	-
Ni	6.2	0.00	1.60	0.01
Ag	1.5	0.00	9.10	0.01
SO4	-	-	210.00	2.00
Sn	1.7	0.00	1.10	0.10
Zn	14.8	0.40	-	-

Table VII-26

MEMBRANE FILTRATION SYSTEM EFFLUENT

Specific Metal	Manufacturers Guarantee	Plant 19066		Plant 31022		Predicted Performance
		In	Out	In	Out	
Al	0.5	---	---	---	---	
Cr, (+6)	0.02	0.46	0.01	5.25	<0.005	
Cr (T)	0.03	4.13	0.018	98.4	0.057	0.05
Cu	0.1	18.8	0.043	8.00	0.222	0.20
Fe	0.1	288	0.3	21.1	0.263	0.30
Pb	0.05	0.652	0.01	0.288	0.01	0.05
CN	0.02	<0.005	<0.005	<0.005	<0.005	0.02
Ni	0.1	9.56	0.017	194	0.352	0.40
Zn	0.1	2.09	0.046	5.00	0.051	0.10
TSS	---	632	0.1	13.0	8.0	1.0

Table VII-27

PEAT ADSORPTION PERFORMANCE

Pollutant (mg/l)	In	Out
Cr+6	35,000	0.04
Cu	250	0.24
CN	36.0	0.7
Pb	20.0	0.025
Hg	1.0	0.02
Ni	2.5	0.07
Ag	1.0	0.05
Sb	2.5	0.9
Zn	1.5	0.25

Table VII-28

ULTRAFILTRATION PERFORMANCE

Parameter	Feed (mg/l)	Permeate (mg/l)
Oil (freon extractable)	1230	4
COD	8920	148
TSS	1380	13
Total Solids	2900	296

TABLE VII-29

REMOVAL OF TOXIC ORGANICS BY OIL REMOVAL

Pollutant Parameter		Influent Concentration (mg/l)	Effluent Concentration (mg/l)
001	acenaphthene	5.7	ND
038	ethylbenzene	0.089	0.01
055	naphthalene	0.75	0.23
062	N-nitrosodiphenylamine	1.5	0.091
065	phenol	0.18	0.04
066	bis(2-ethylhexyl)phthalate	1.25	0.01
068	di-n-butyl phthalate	1.27	0.019
078/081	anthracene/phenanthrene	2.0	0.1
080	fluorene	0.76	0.035
084	pyrene	0.075	0.01
085	tetrachloroethylene	4.2	0.1
086	toluene	0.16	0.02
087	trichloroethylene	4.8	0.01
097	endosulfan sulfate	0.012	ND
098	endrin	0.066	0.005
107	PCB-1254 (a)	1.1	0.005
110	PCB-1248 (b)	1.8	0.005
	(mg/l)	25.7	0.690

a: PCB-1242, PCB-1254, PCB-1221, PCB-1232 reported together.
b: PCB-1248, PCB-1260, PCB-1016 reported together.

TABLE VII-30

CHEMICAL EMULSION BREAKING EFFICIENCIES

Parameter	Concentration (mg/l) Influent	Concentration (mg/l) Effluent	Reference
O&G	6,060	98	Sampling data*
TSS	2,612	46	
O&G	13,000	277	Sampling data+
	18,400	---	
	21,300	189	
TSS	540	121	
	680	59	
	1,060	140	
O&G	2,300	52	Sampling data**
	12,500	27	
	13,800	18	
TSS	1,650	187	
	2,200	153	
	3,470	63	
O&G	7,200	80	Katnick and Pavilcius, 1978

---

*Oil and grease and total suspended solids were taken as grab samples before and after batch emulsion breaking treatment which used alumn and polymer on emulsified rolling oil wastewater.

+Oil and grease (grab) and total suspended solids (grab) samples were taken on three consecutive days from emulsified rolling oil wastewater. A commercial demulsifier was used in this batch treatment.

**Oil and grease (grab) and total suspended solids (composite) samples were taken on three consecutive days from emulsified rolling oil wastewater. A commercial demulsifier (polymer) was used in this batch treatment.

++This result is from a full-scale batch chemical treatment system for emulsified oils from a steel rolling mill.

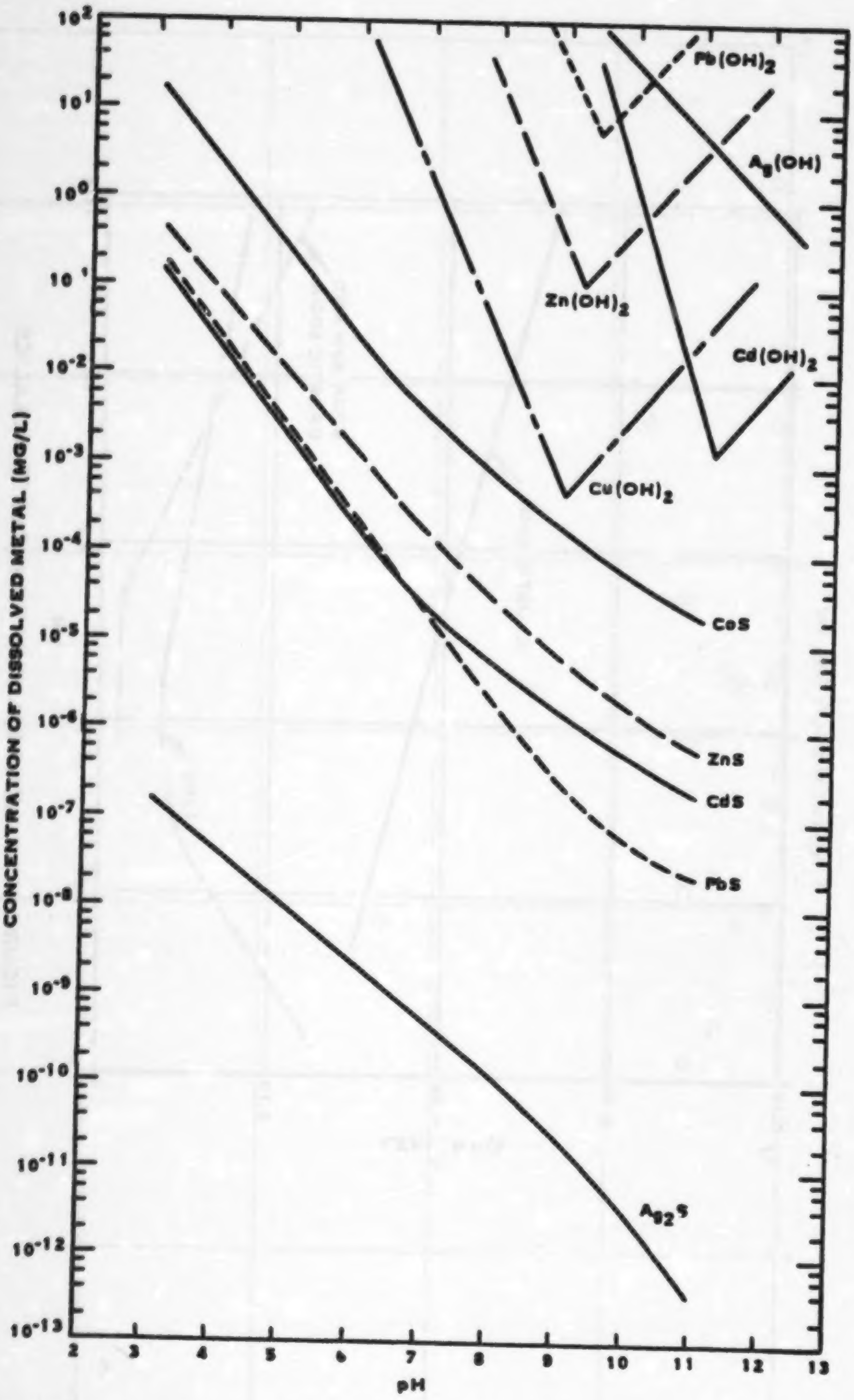


FIGURE VII-1. COMPARATIVE SOLUBILITIES OF METAL HYDROXIDES AND SULFIDE AS A FUNCTION OF pH

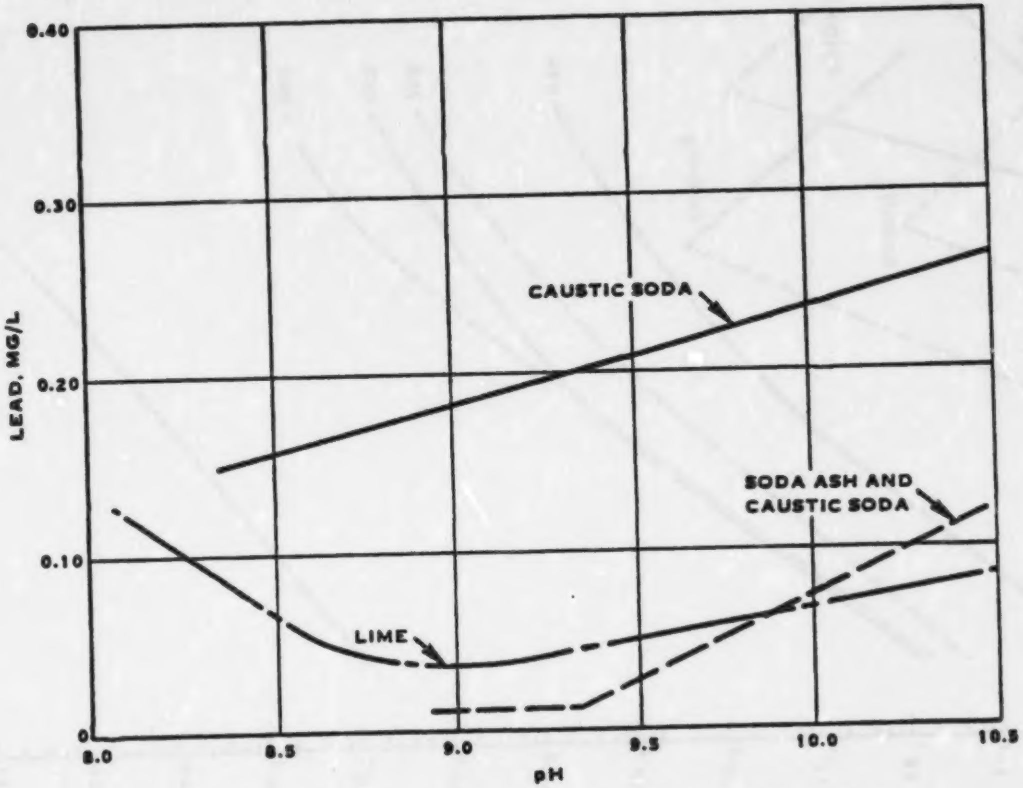


FIGURE VII-2. LEAD SOLUBILITY IN THREE ALKALIES

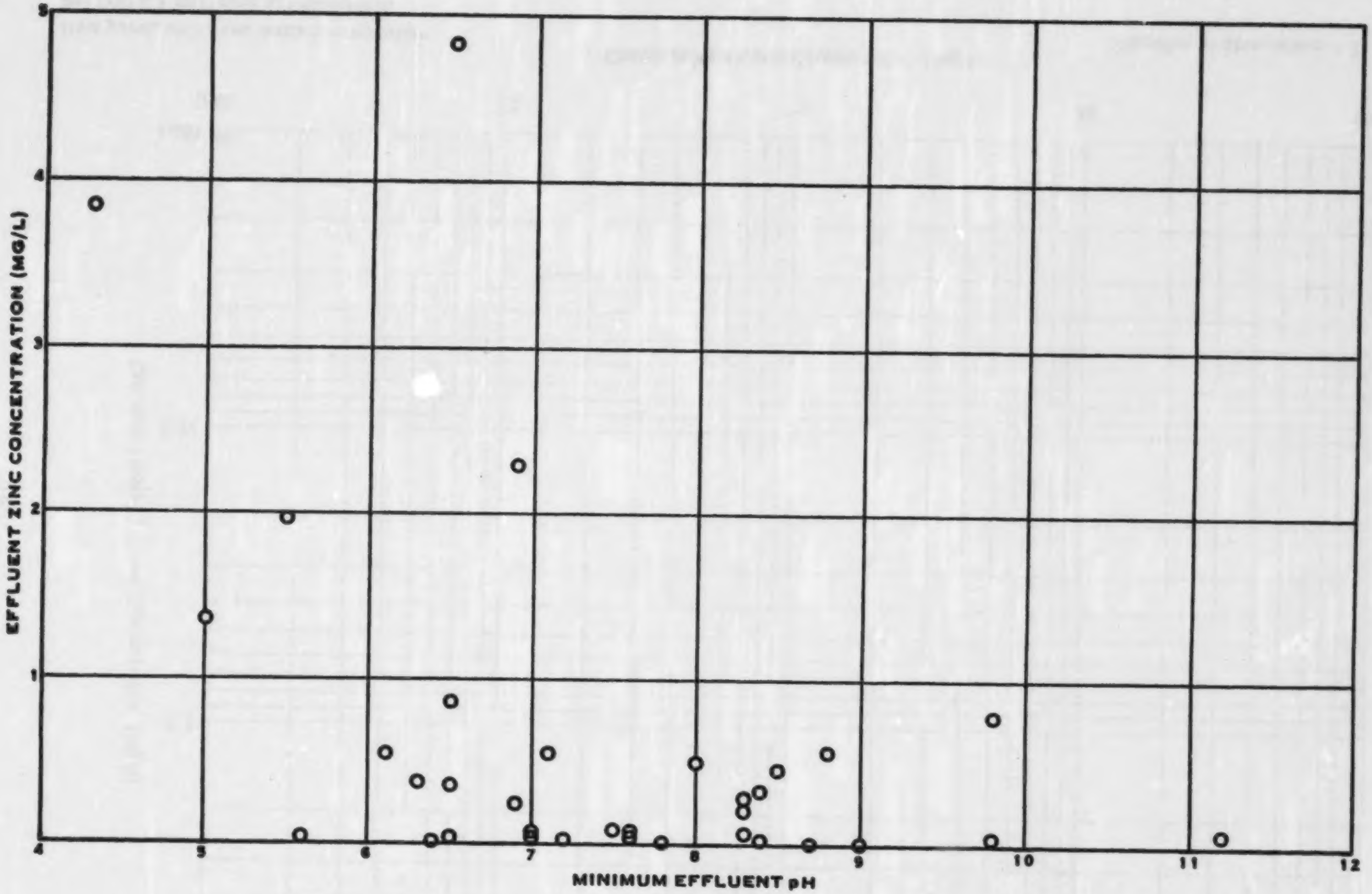
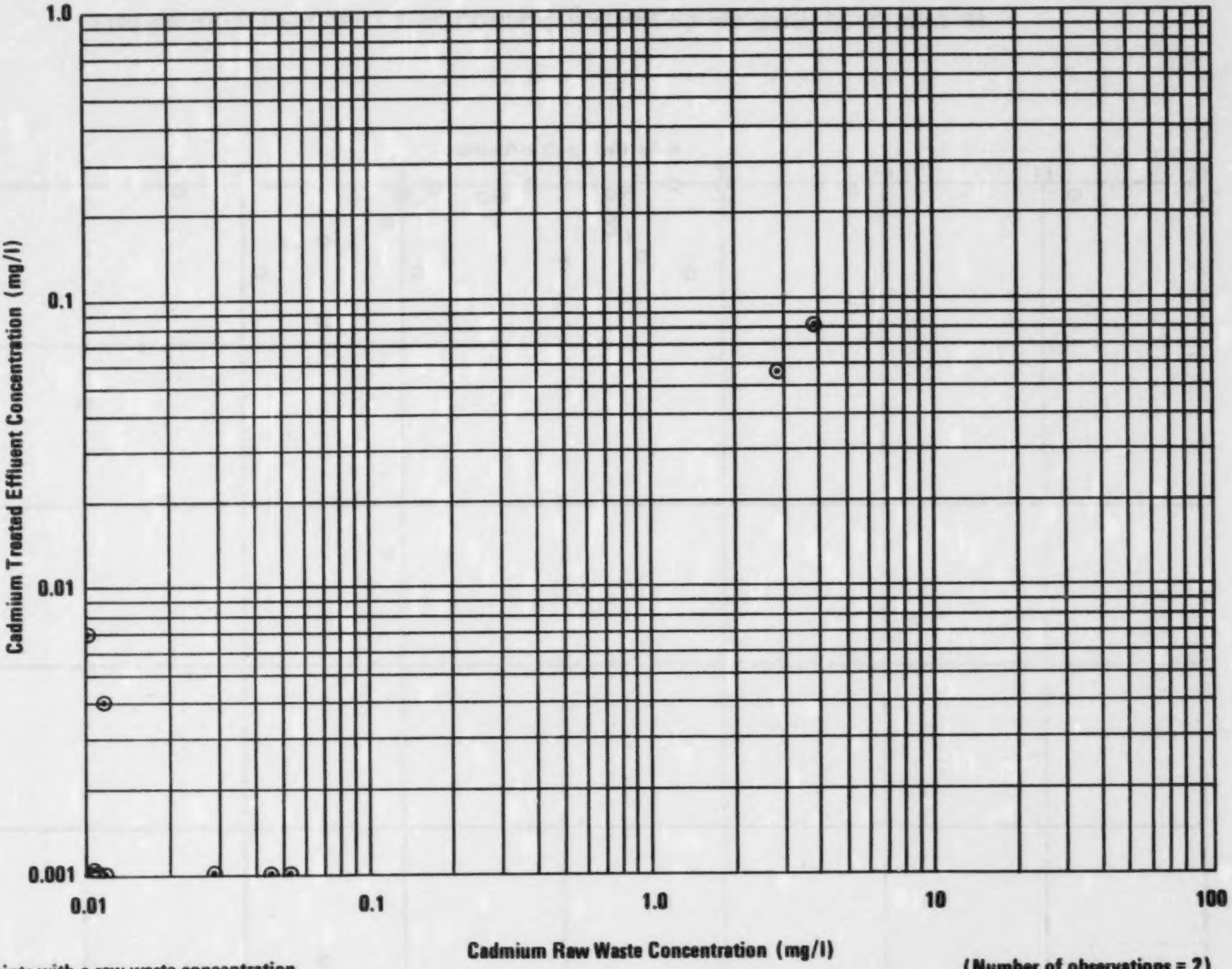


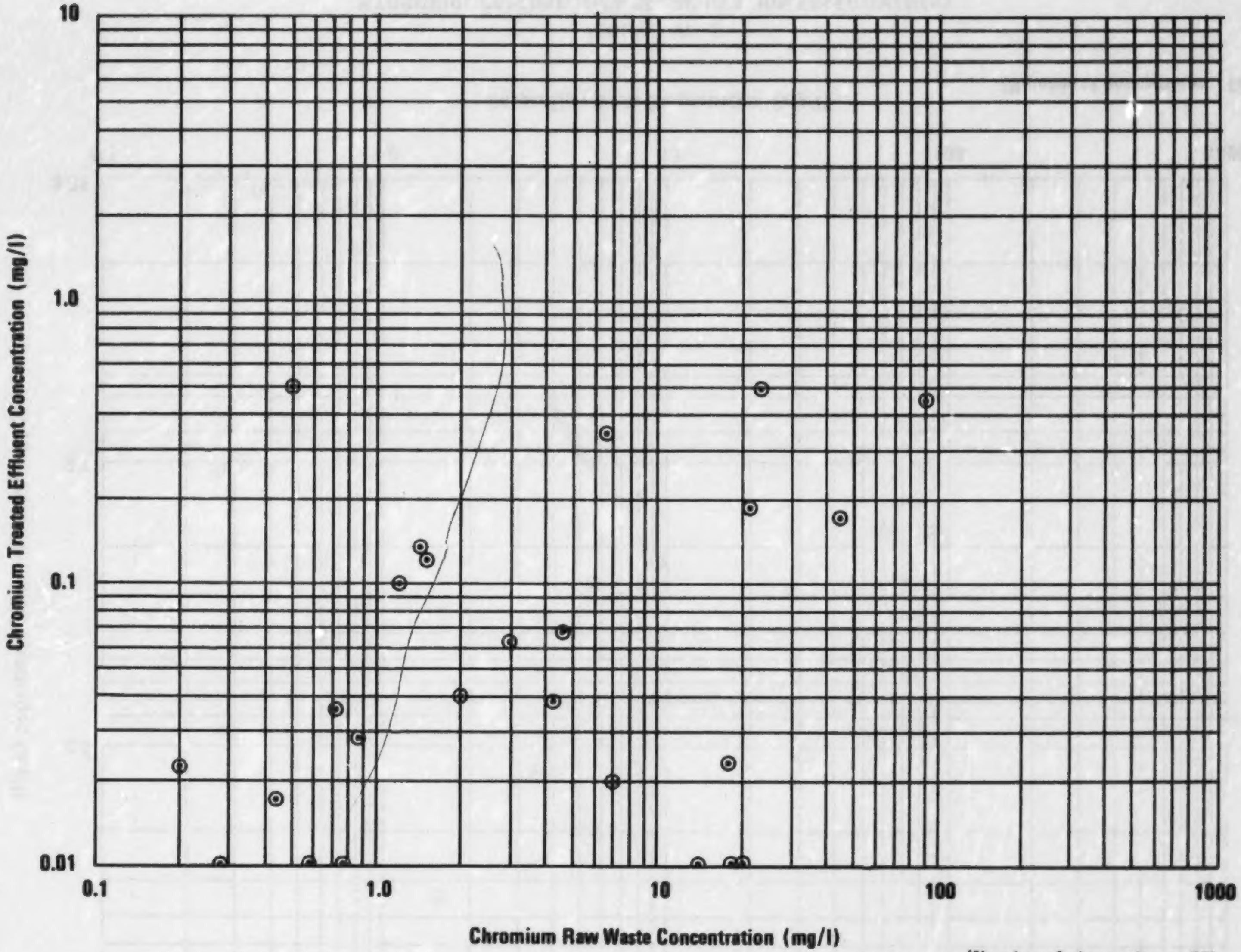
FIGURE VII-3. EFFLUENT ZINC CONCENTRATION VS. MINIMUM EFFLUENT pH



(Number of observations = 2)

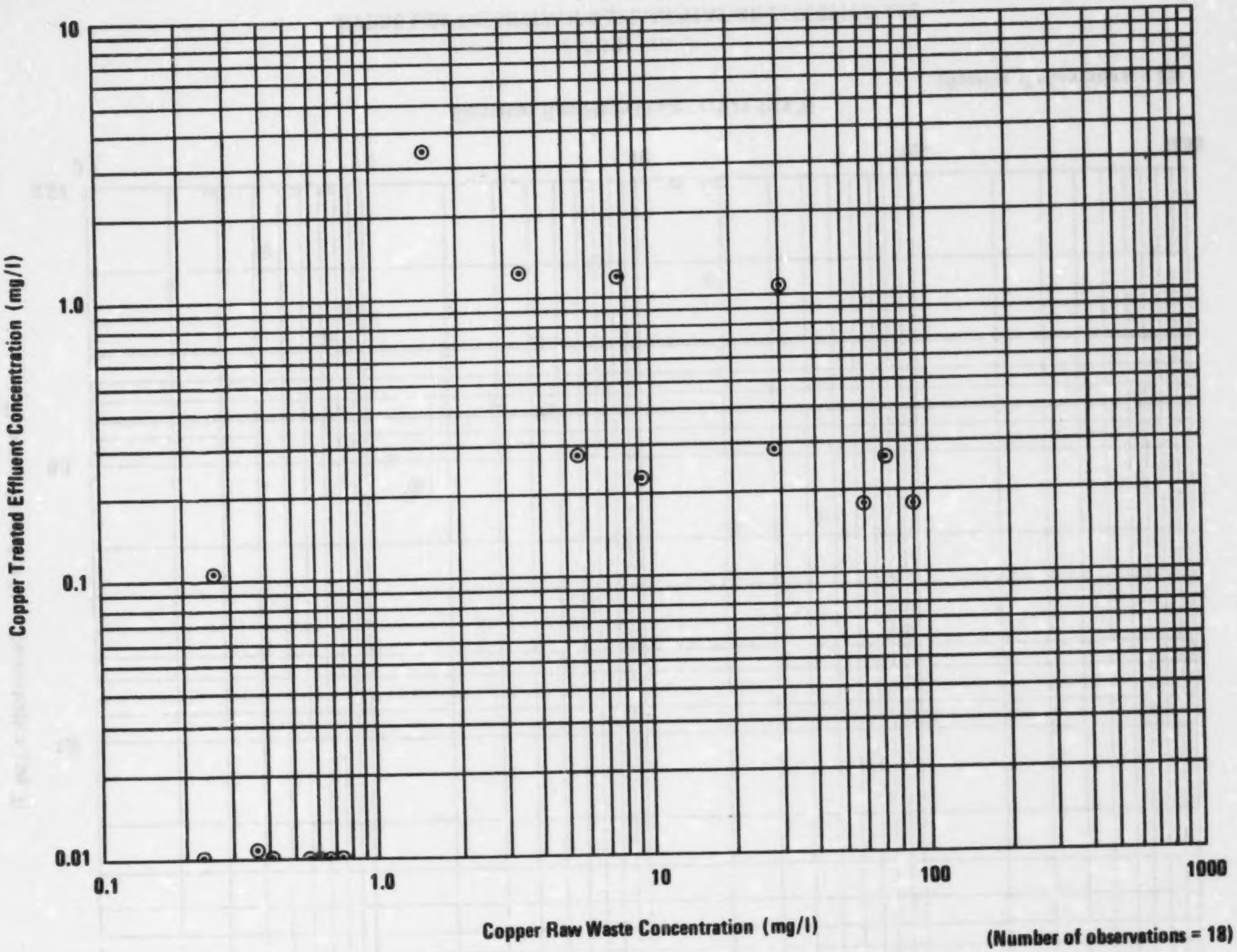
Data points with a raw waste concentration less than 0.1 mg/l were not included in treatment effectiveness calculations.

FIGURE VII-4
HYDROXIDE PRECIPITATION SEDIMENTATION EFFECTIVENESS
CADMIUM



(Number of observations = 25)

FIGURE VII-5
HYDROXIDE PRECIPITATION SEDIMENTATION EFFECTIVENESS
CHROMIUM



(Number of observations = 18)

FIGURE VII-6
HYDROXIDE PRECIPITATION SEDIMENTATION EFFECTIVENESS
COPPER

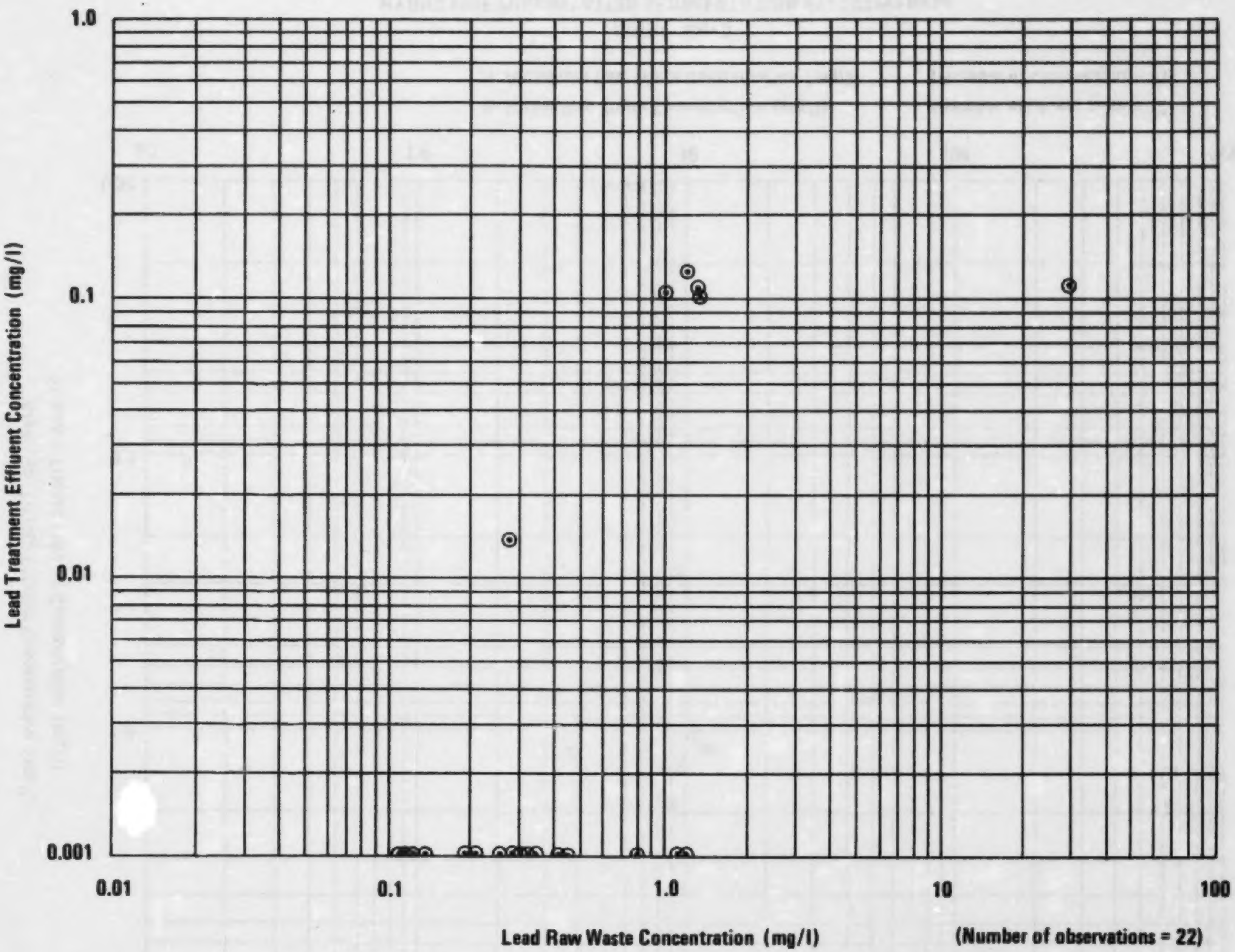


FIGURE VII-7
HYDROXIDE PRECIPITATION SEDIMENTATION EFFECTIVENESS
LEAD

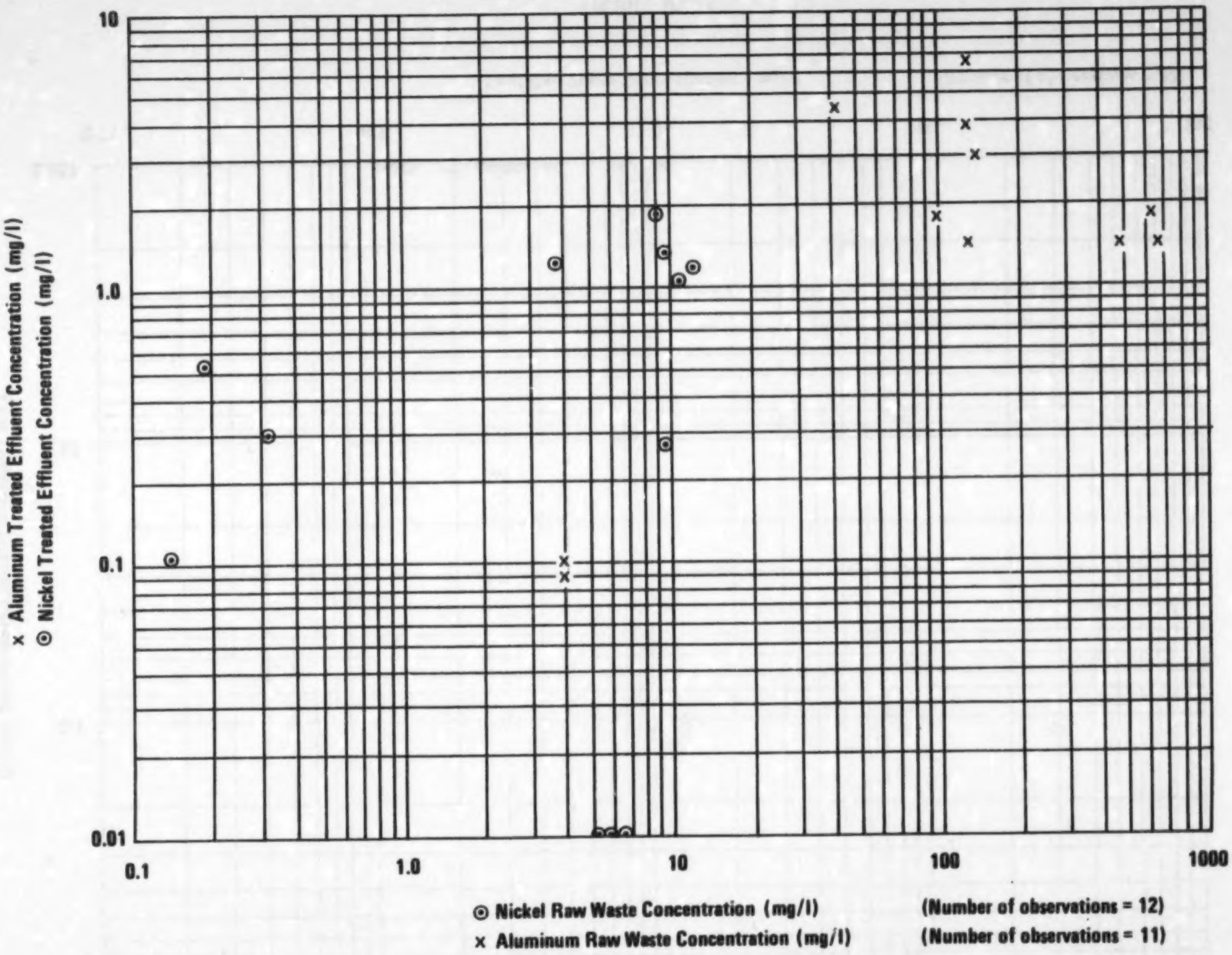
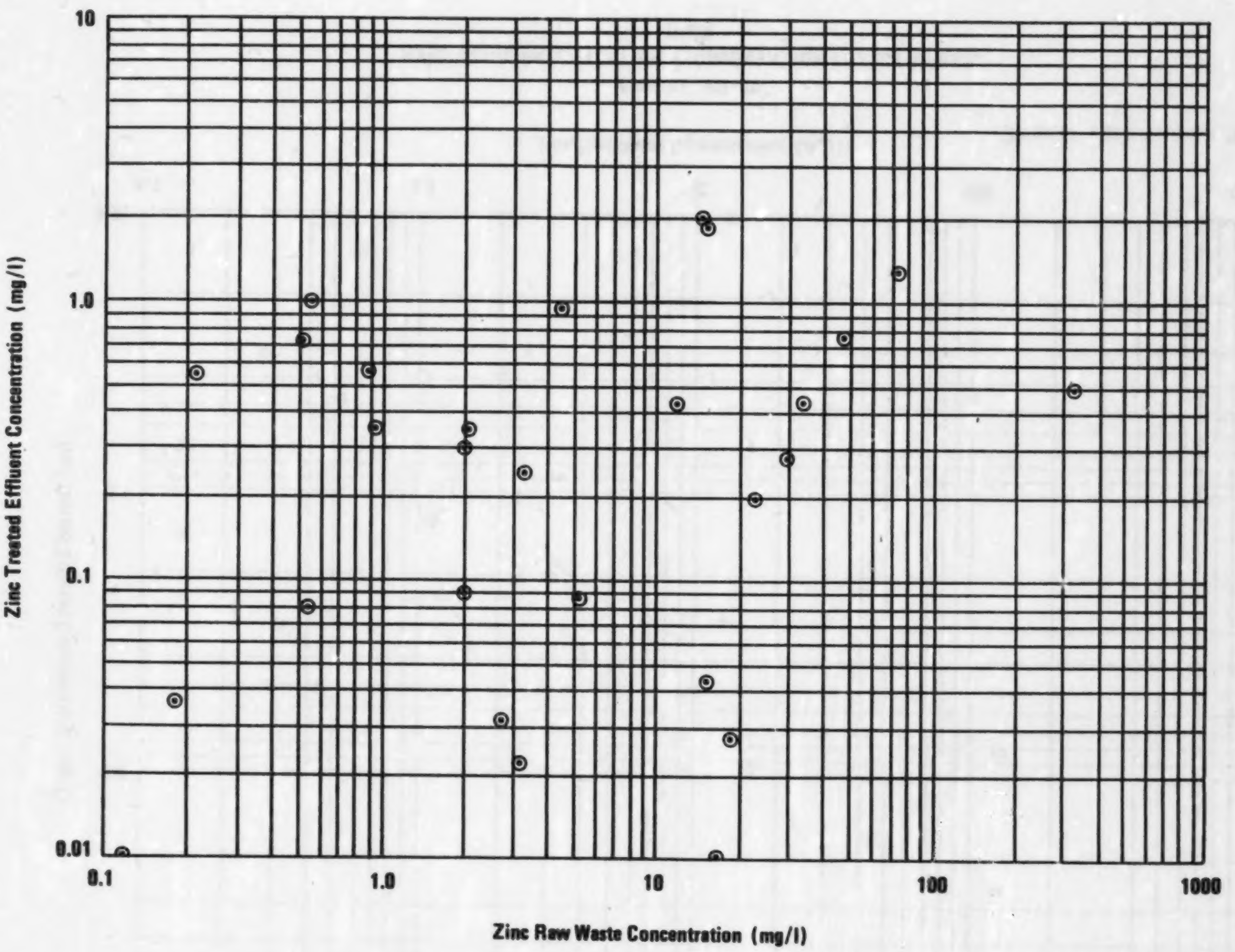


FIGURE VII-8
HYDROXIDE PRECIPITATION SEDIMENTATION EFFECTIVENESS
NICKEL AND ALUMINUM



(Number of observations = 28)

FIGURE VII-9
HYDROXIDE PRECIPITATION SEDIMENTATION EFFECTIVENESS
ZINC

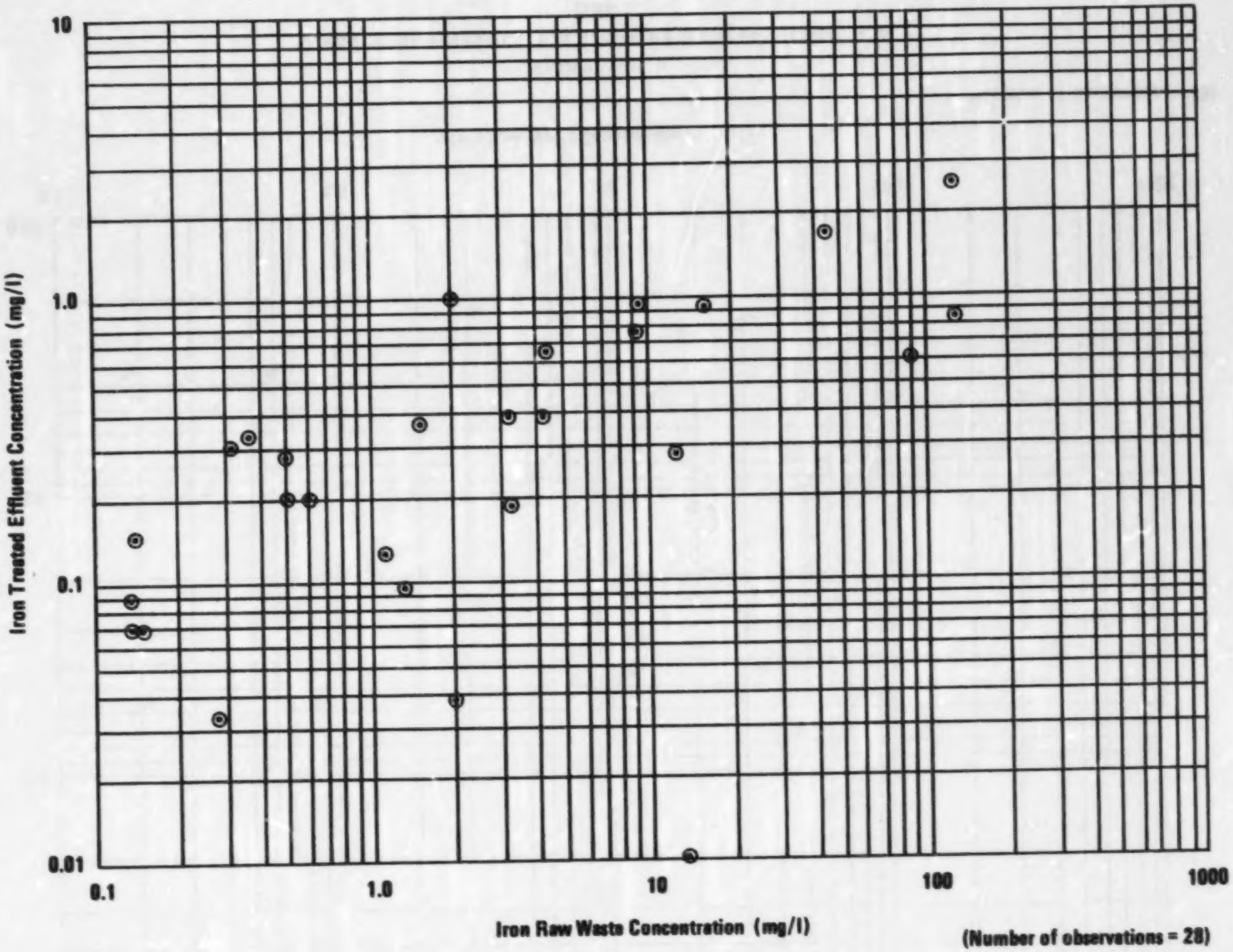
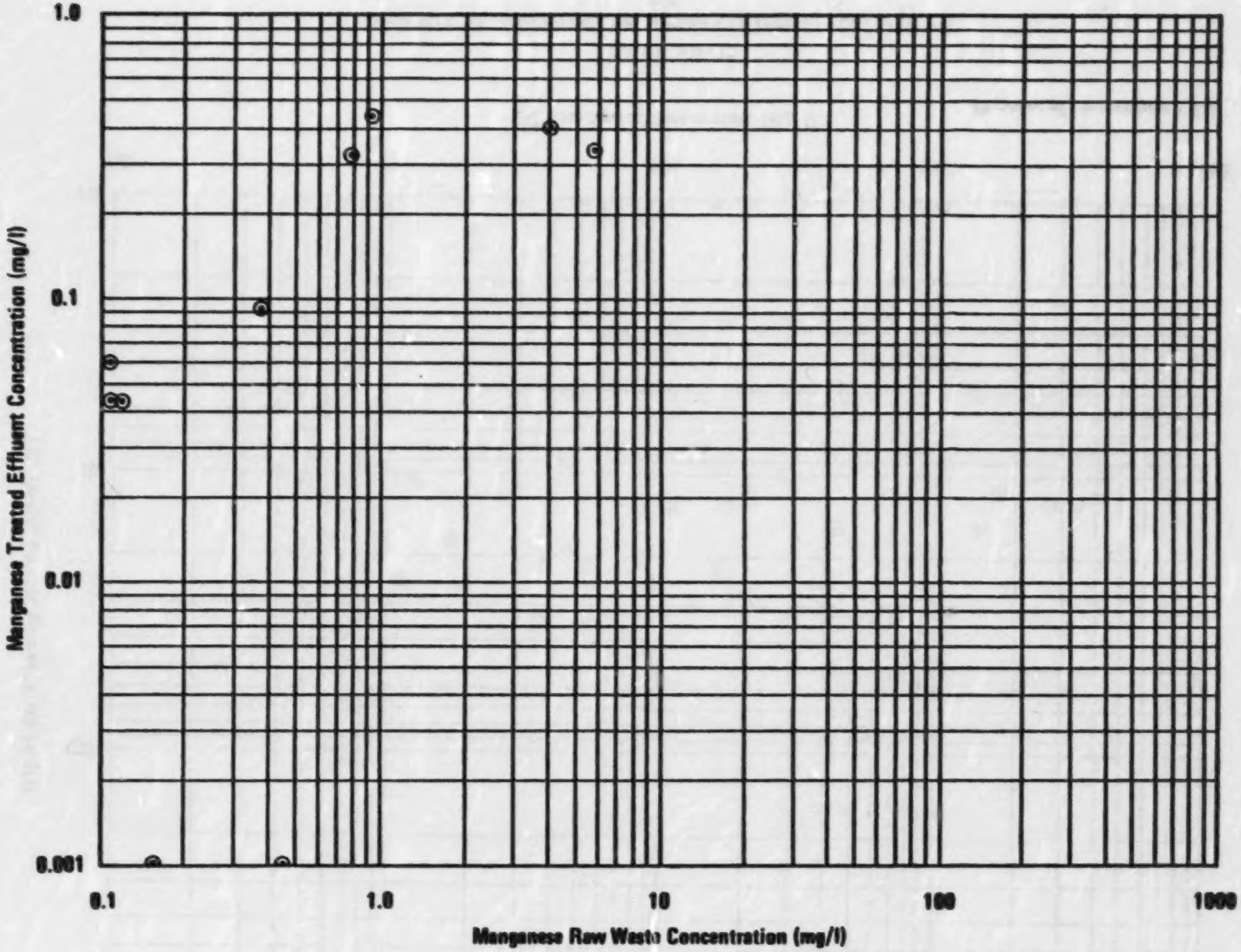


FIGURE VII-10
HYDROXIDE PRECIPITATION SEDIMENTATION EFFECTIVENESS
IRON



(Number of observations = 10)

FIGURE VII–11
HYDROXIDE PRECIPITATION SEDIMENTATION EFFECTIVENESS
MANGANESE

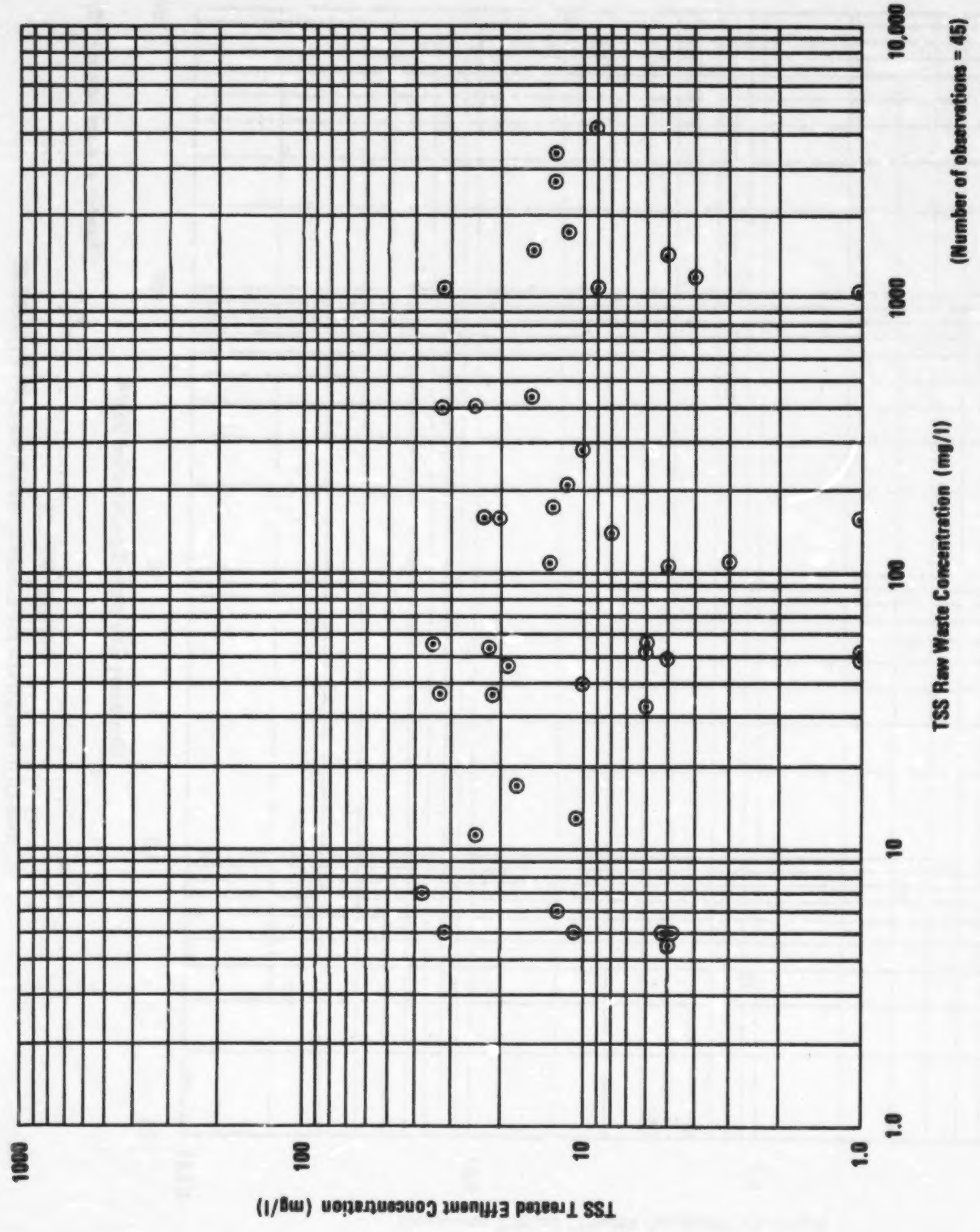


FIGURE VII-12
HYDROXIDE PRECIPITATION SEDIMENTATION EFFECTIVENESS
TSS

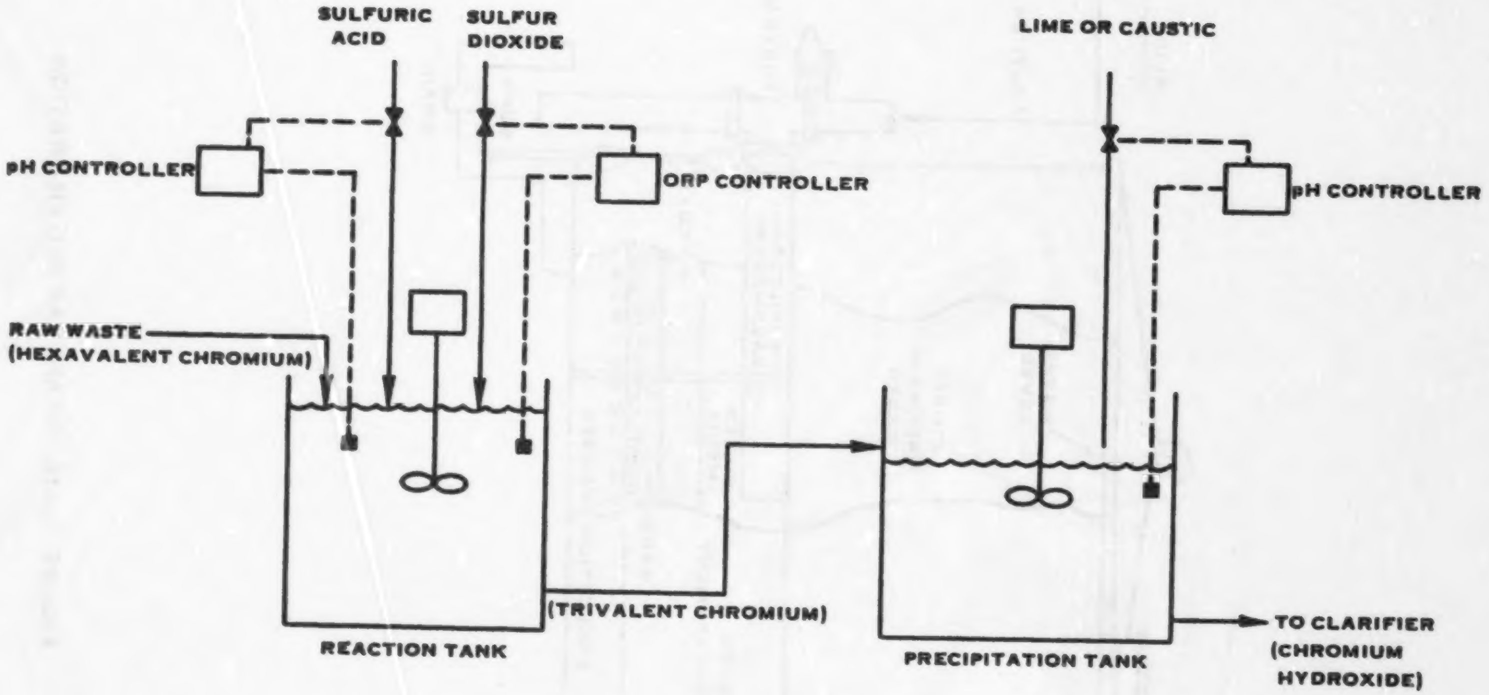

SULFURIC ACID
SULFUR DIOXIDE
LIME OR CAUSTIC
pH CONTROLLER
ORP CONTROLLER
pH CONTROLLER
RAW WASTE
(HEXAVALENT CHROMIUM)
(TRIVALENT CHROMIUM)
REACTION TANK
PRECIPITATION TANK
TO CLARIFIER
(CHROMIUM
HYDROXIDE)

FIGURE VII-13. HEXAVALENT CHROMIUM REDUCTION WITH SULFUR DIOXIDE

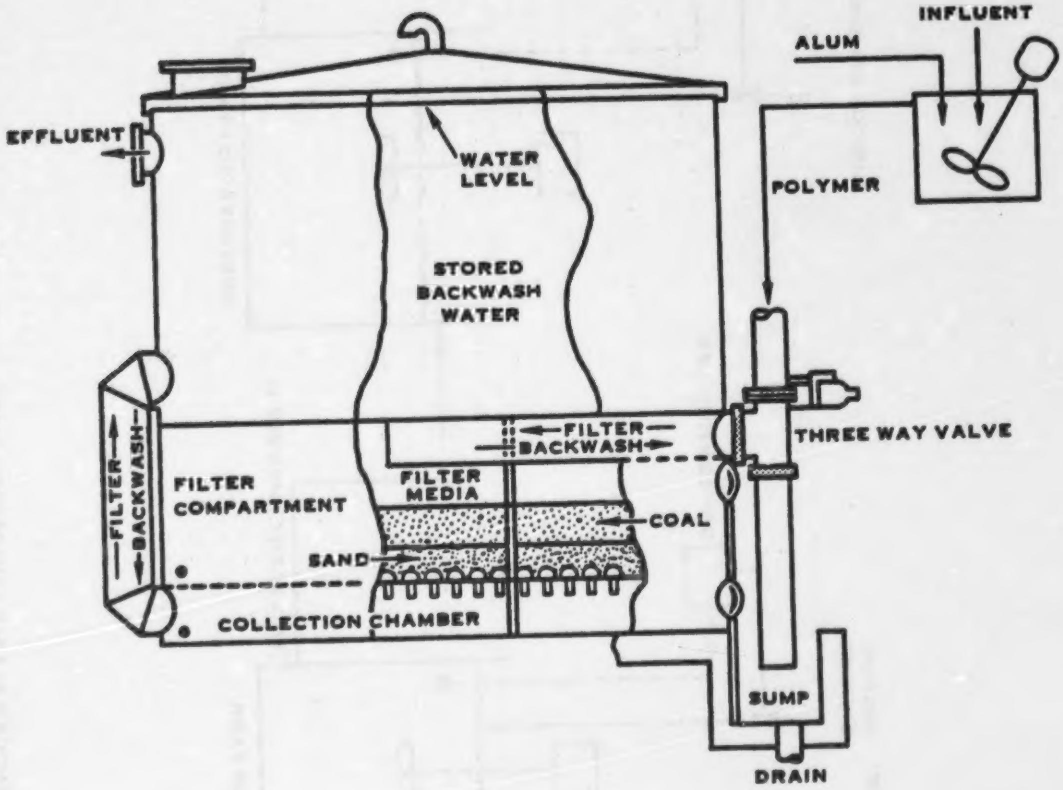

INFLUENT
ALUM
EFFLUENT
WATER LEVEL
POLYMER
STORED BACKWASH WATER
FILTER
BACKWASH
THREE WAY VALVE
FILTER
BACKWASH
FILTER COMPARTMENT
FILTER MEDIA
COAL
SAND
COLLECTION CHAMBER
SUMP
DRAIN

FIGURE VII-14. GRANULAR BED FILTRATION

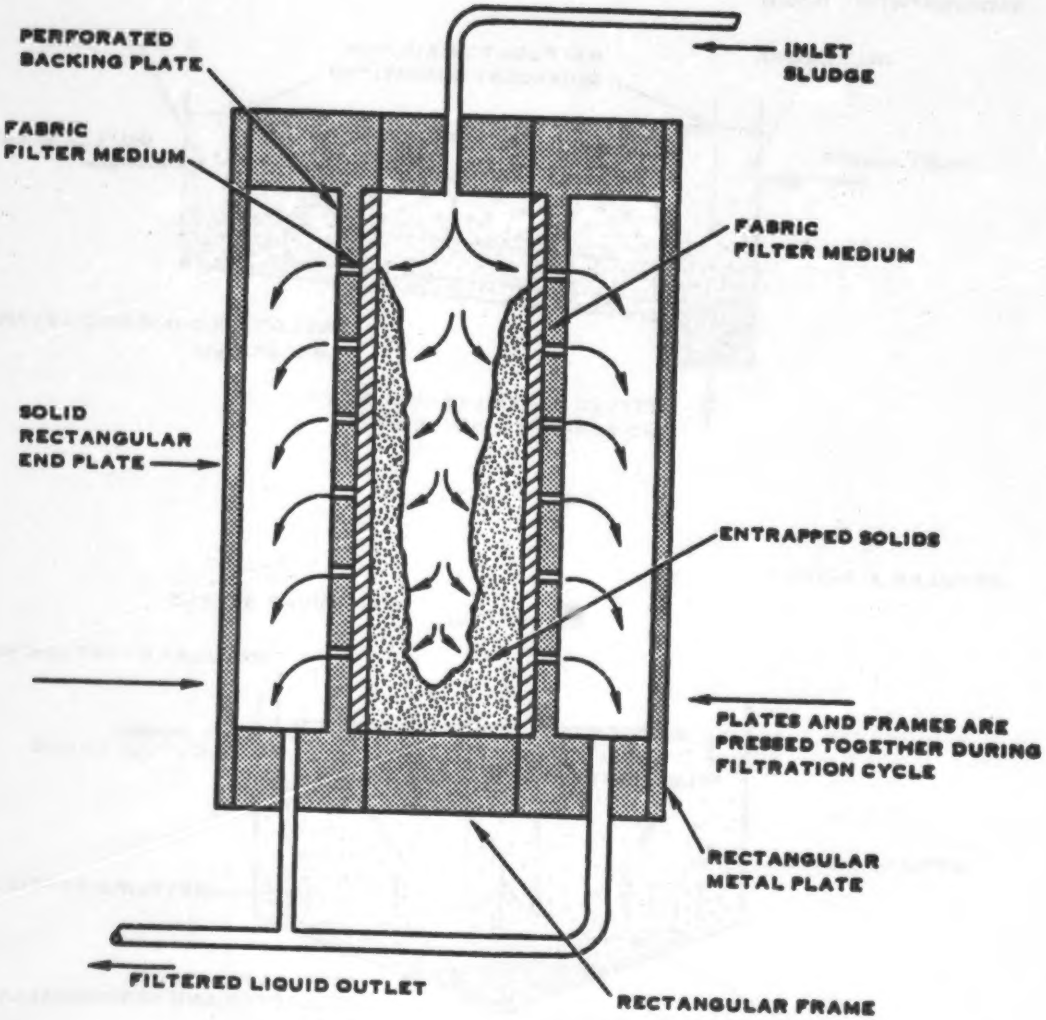
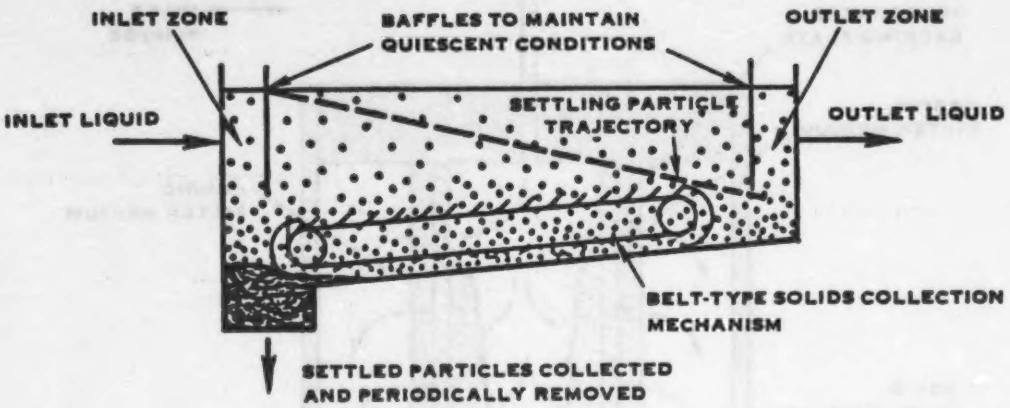

PERFORATED BACKING PLATE
FABRIC FILTER MEDIUM
INLET SLUDGE
FABRIC FILTER MEDIUM
SOLID RECTANGULAR END PLATE
ENTRAPPED SOLIDS
PLATES AND FRAMES ARE PRESSED TOGETHER DURING FILTRATION CYCLE
RECTANGULAR METAL PLATE
FILTERED LIQUID OUTLET
RECTANGULAR FRAME

FIGURE VII-15. PRESSURE FILTRATION

SEDIMENTATION BASIN


INLET ZONE
BAFFLES TO MAINTAIN QUIESCENT CONDITIONS
OUTLET ZONE
INLET LIQUID
SETTLING PARTICLE TRAJECTORY
OUTLET LIQUID
BELT-TYPE SOLIDS COLLECTION MECHANISM
SETTLED PARTICLES COLLECTED AND PERIODICALLY REMOVED

CIRCULAR CLARIFIER

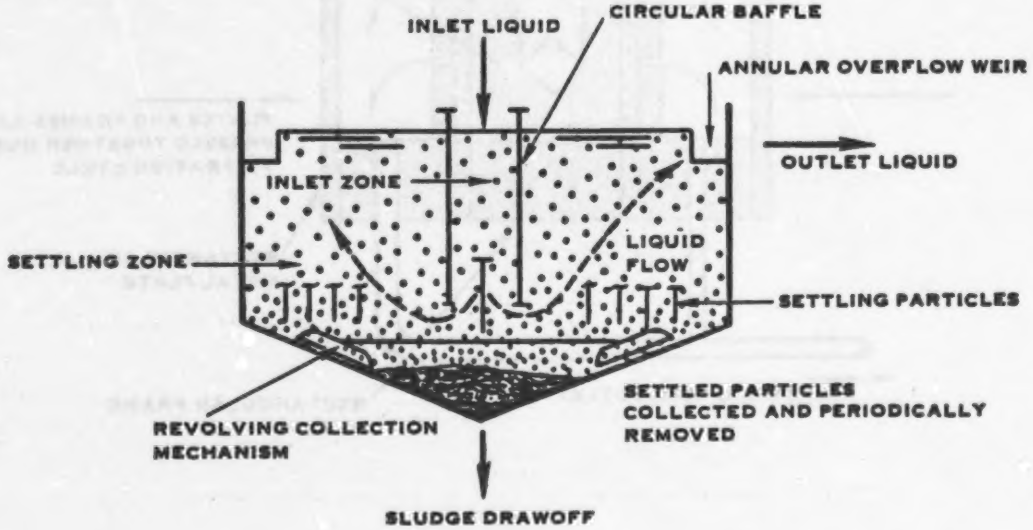

INLET LIQUID
CIRCULAR BAFFLE
ANNULAR OVERFLOW WEIR
OUTLET LIQUID
INLET ZONE
SETTLING ZONE
LIQUID FLOW
SETTLING PARTICLES
SETTLED PARTICLES COLLECTED AND PERIODICALLY REMOVED
REVOLVING COLLECTION MECHANISM
SLUDGE DRAWOFF

FIGURE VII-16. REPRESENTATIVE TYPES OF SEDIMENTATION

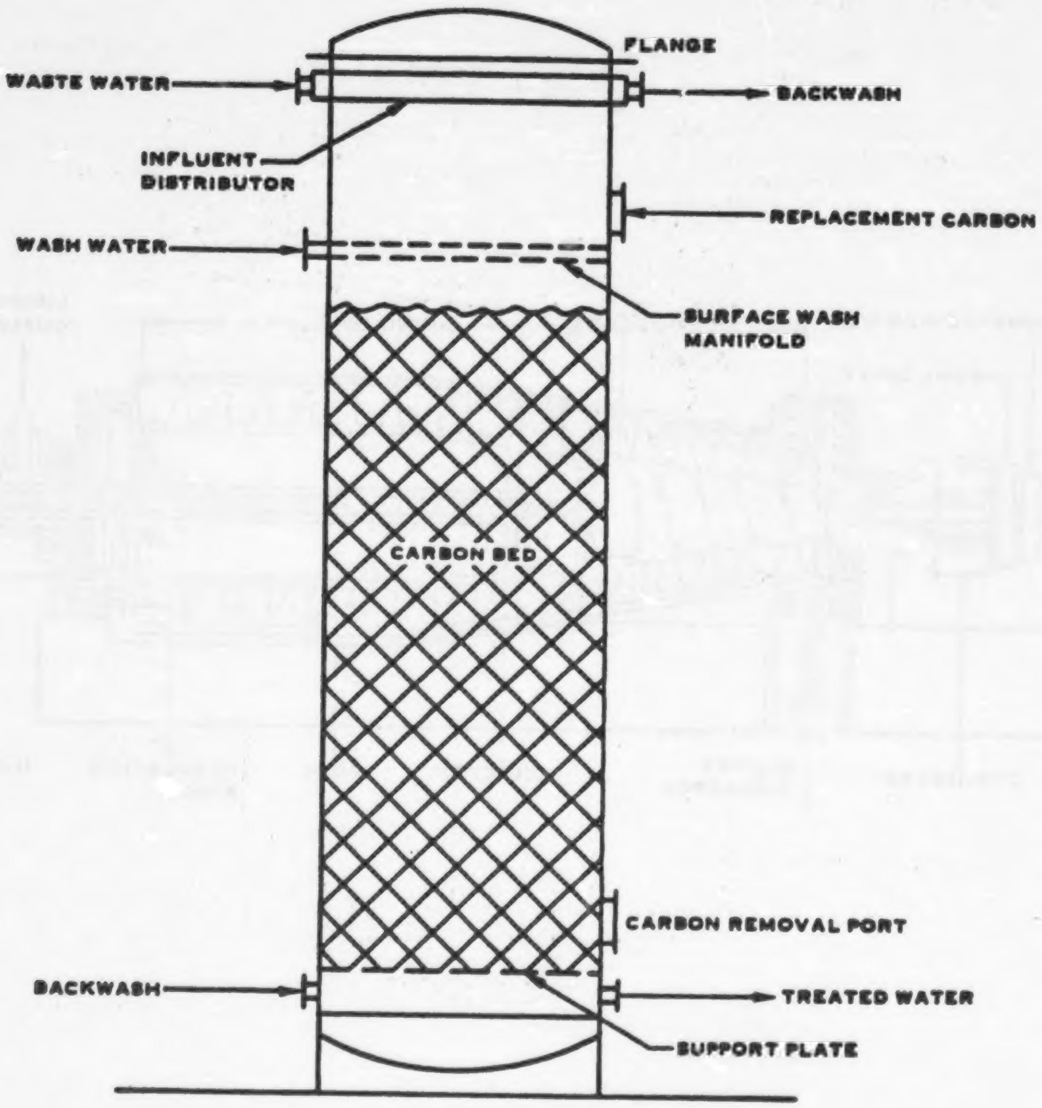

FLANGE
WASTE WATER
BACKWASH
INFLUENT DISTRIBUTOR
REPLACEMENT CARBON
WASH WATER
SURFACE WASH MANIFOLD
CARBON BED
CARBON REMOVAL PORT
BACKWASH
TREATED WATER
SUPPORT PLATE

FIGURE VII-17. ACTIVATED CARBON ADSORPTION COLUMN

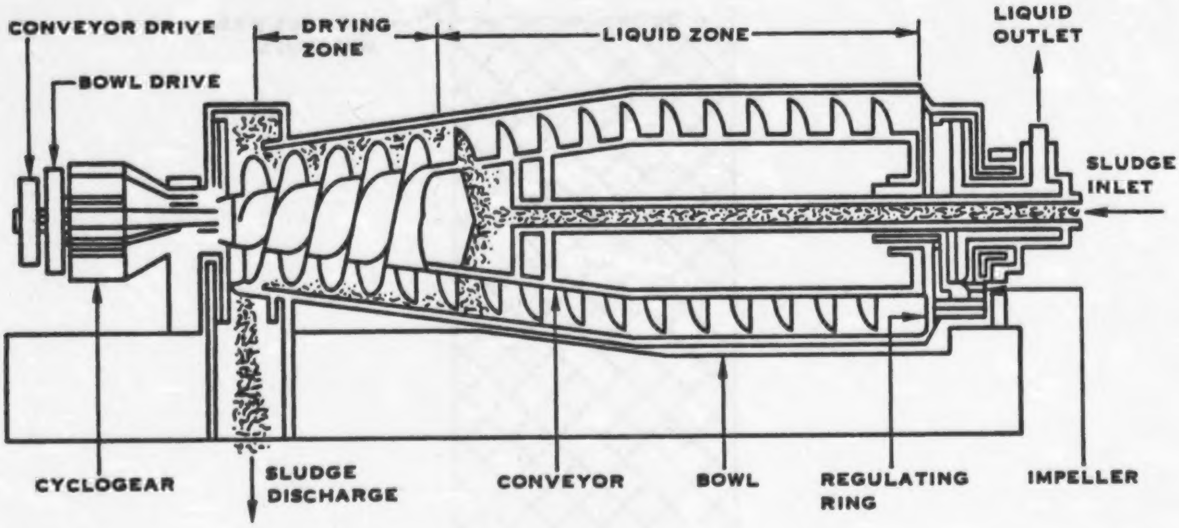

CONVEYOR DRIVE
BOWL DRIVE
DRYING ZONE
LIQUID ZONE
LIQUID OUTLET
SLUDGE INLET
CYCLOGEAR
SLUDGE DISCHARGE
CONVEYOR
BOWL
REGULATING RING
IMPELLER

FIGURE VII-18. CENTRIFUGATION

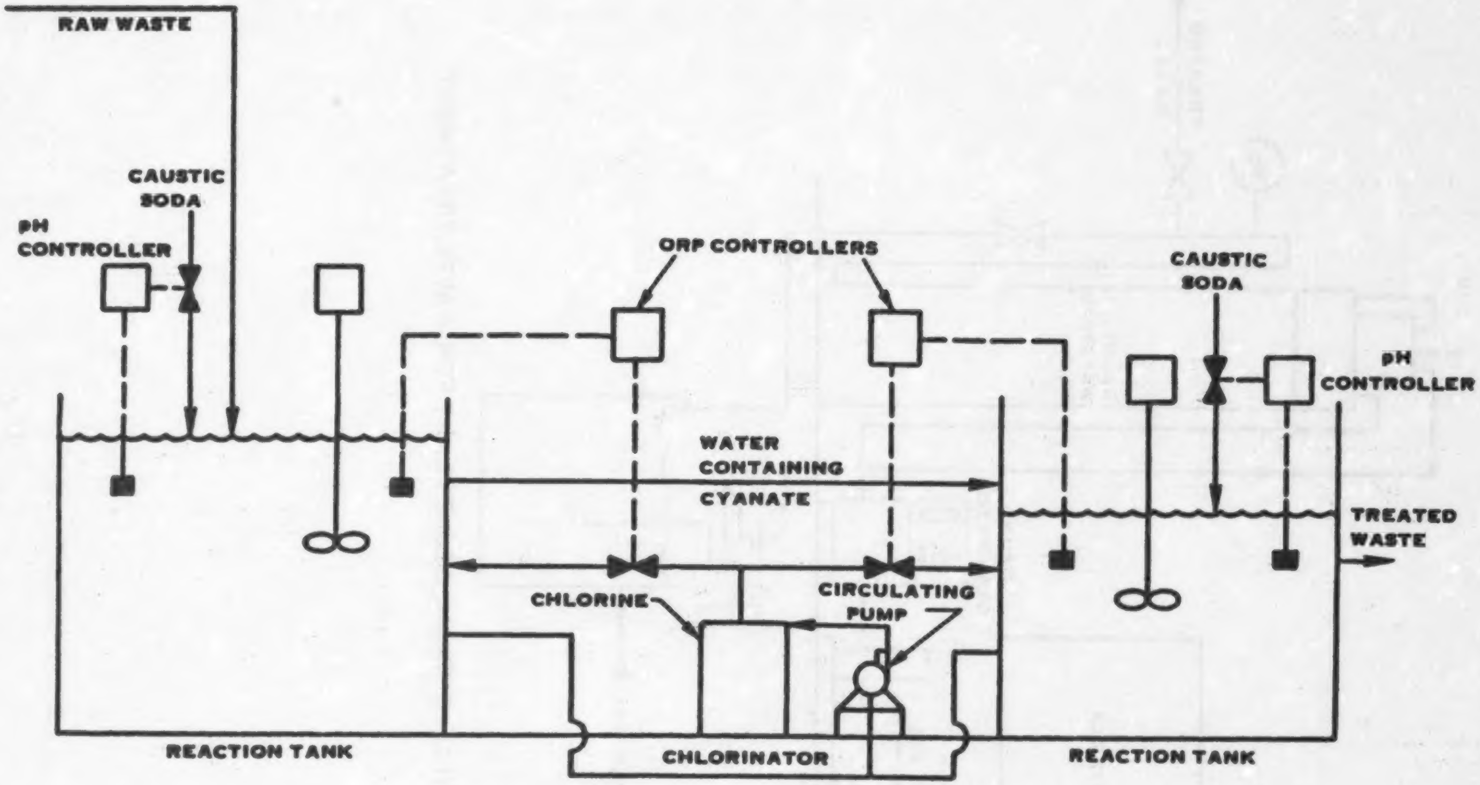

RAW WASTE
CAUSTIC SODA
pH CONTROLLER
ORP CONTROLLERS
CAUSTIC SODA
pH CONTROLLER
WATER CONTAINING CYANATE
TREATED WASTE
CHLORINE
CIRCULATING PUMP
REACTION TANK
CHLORINATOR
REACTION TANK

FIGURE VII-19. TREATMENT OF CYANIDE WASTE BY ALKALINE CHLORINATION

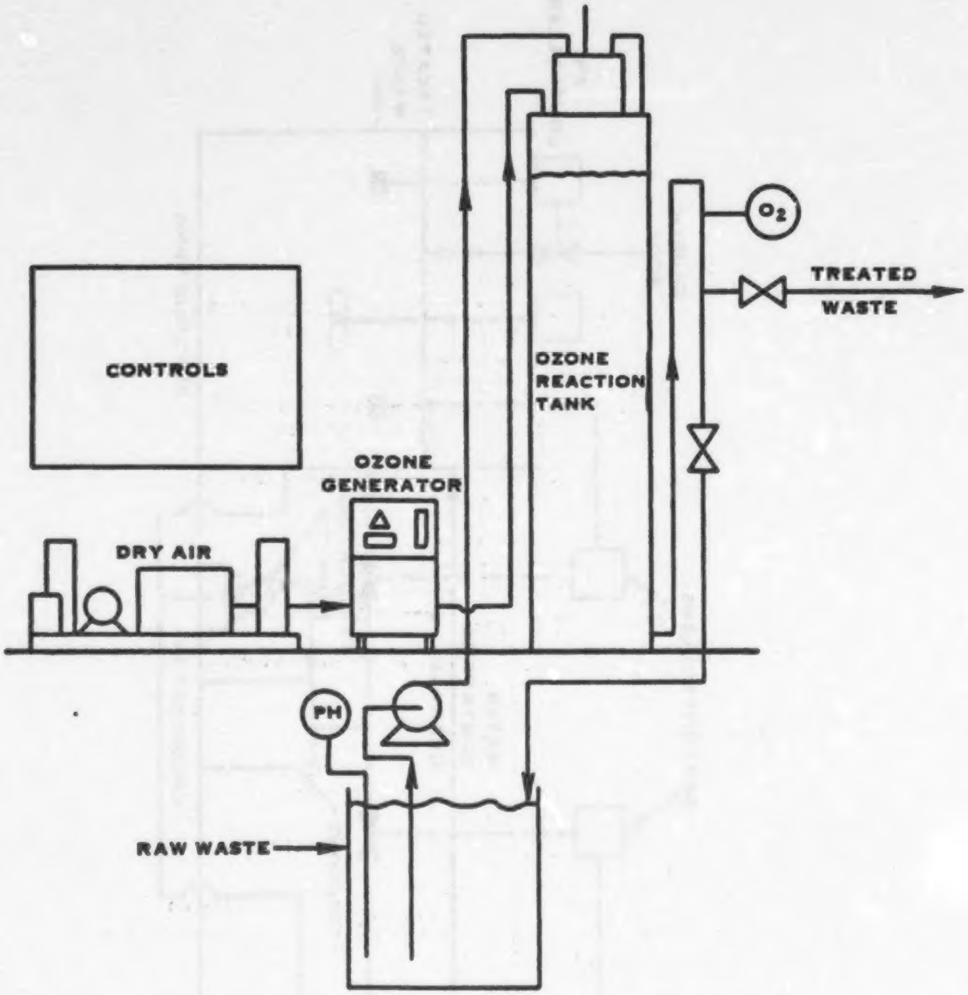

CONTROLS
DRY AIR
OZONE GENERATOR
OZONE REACTION TANK
O_2
TREATED WASTE
PH
RAW WASTE

FIGURE VII-20. TYPICAL OZONE PLANT FOR WASTE TREATMENT

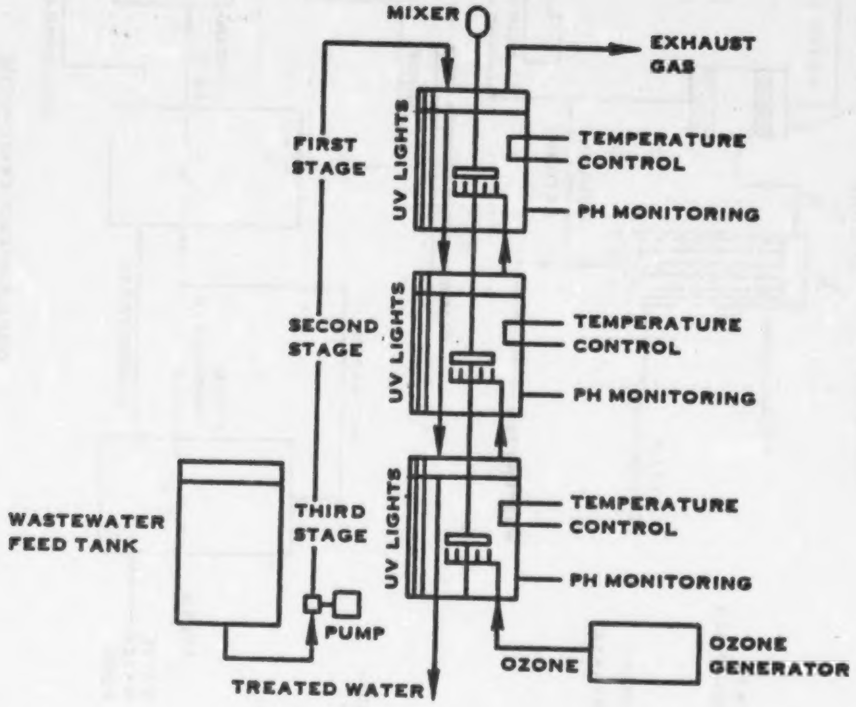

MIXER
EXHAUST GAS
FIRST STAGE
UV LIGHTS
TEMPERATURE CONTROL
PH MONITORING
SECOND STAGE
UV LIGHTS
TEMPERATURE CONTROL
PH MONITORING
WASTEWATER FEED TANK
THIRD STAGE
UV LIGHTS
TEMPERATURE CONTROL
PH MONITORING
PUMP
OZONE
OZONE GENERATOR
TREATED WATER

FIGURE VII-21. UV/OZONATION

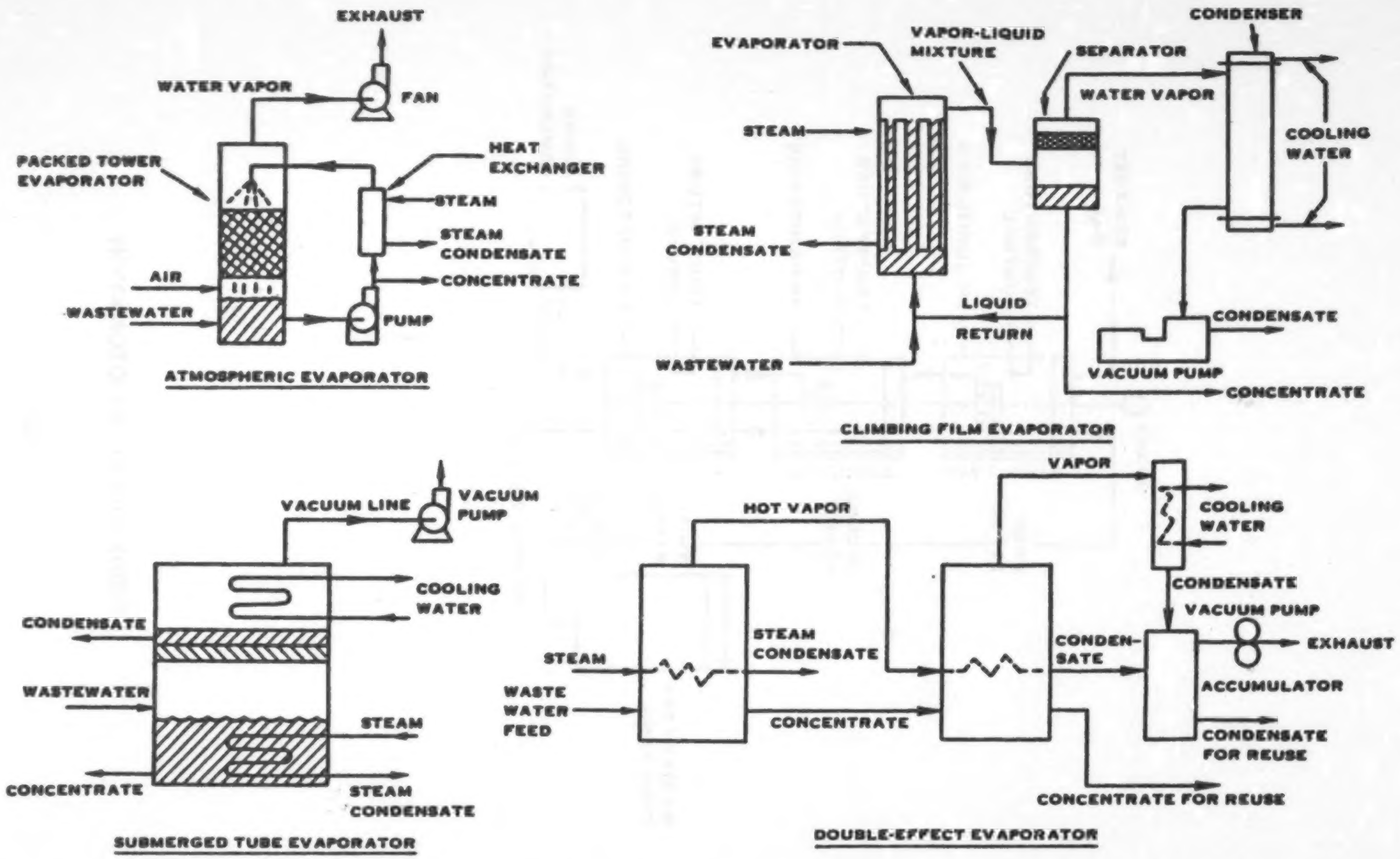

EXHAUST
WATER VAPOR
FAN
PACKED TOWER EVAPORATOR
HEAT EXCHANGER
STEAM
STEAM CONDENSATE
AIR
CONCENTRATE
WASTEWATER
PUMP
ATMOSPHERIC EVAPORATOR
EVAPORATOR
VAPOR-LIQUID MIXTURE
SEPARATOR
CONDENSER
WATER VAPOR
STEAM
COOLING WATER
STEAM CONDENSATE
LIQUID RETURN
CONDENSATE
WASTEWATER
VACUUM PUMP
CONCENTRATE
CLIMBING FILM EVAPORATOR
VACUUM LINE
VACUUM PUMP
COOLING WATER
CONDENSATE
WASTEWATER
STEAM
CONCENTRATE
STEAM CONDENSATE
SUBMERGED TUBE EVAPORATOR
VAPOR
HOT VAPOR
COOLING WATER
CONDENSATE
VACUUM PUMP
STEAM
STEAM CONDENSATE
CONDEN-SATE
EXHAUST
WASTE WATER FEED
ACCUMULATOR
CONCENTRATE
CONDENSATE FOR REUSE
CONCENTRATE FOR REUSE
DOUBLE-EFFECT EVAPORATOR

FIGURE VII-22. TYPES OF EVAPORATION EQUIPMENT

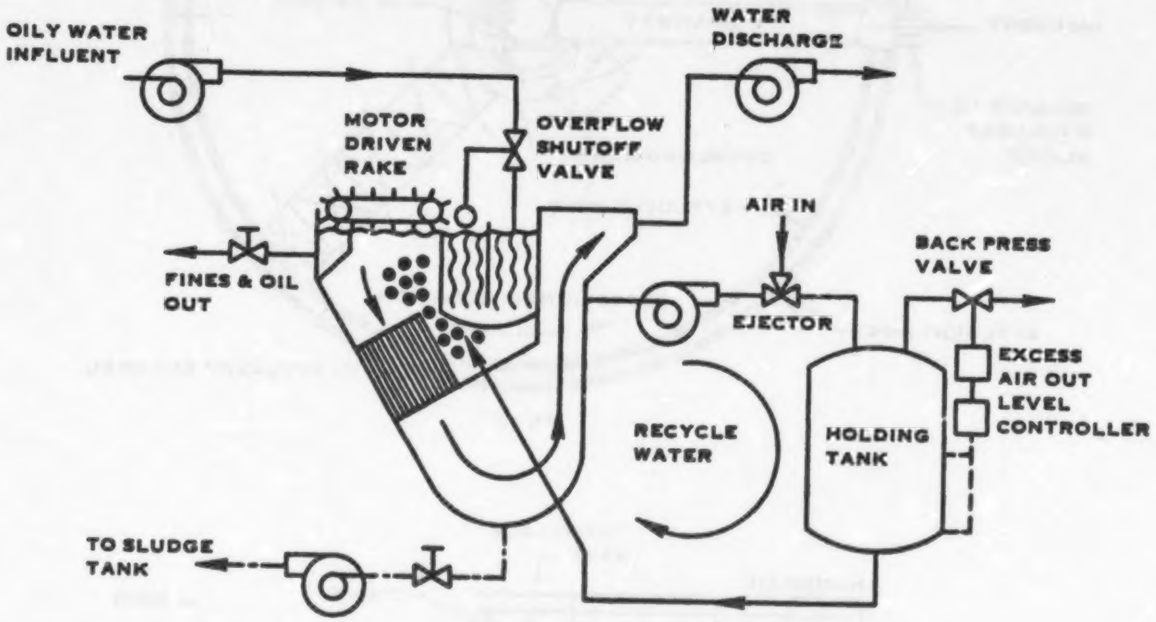
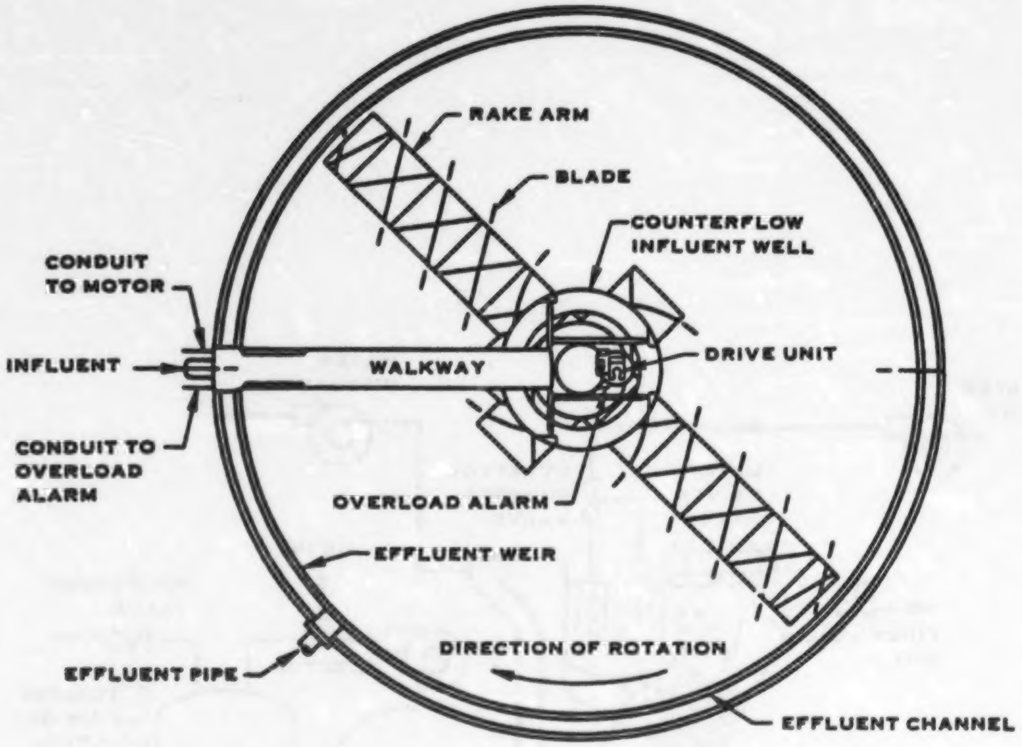

OILY WATER INFLUENT
WATER DISCHARGE
MOTOR DRIVEN RAKE
OVERFLOW SHUTOFF VALVE
AIR IN
BACK PRESS VALVE
FINES & OIL OUT
EJECTOR
EXCESS AIR OUT
LEVEL CONTROLLER
RECYCLE WATER
HOLDING TANK
TO SLUDGE TANK

FIGURE VII-23. DISSOLVED AIR FLOTATION


RAKE ARM
BLADE
COUNTERFLOW INFLUENT WELL
CONDUIT TO MOTOR
INFLUENT
WALKWAY
DRIVE UNIT
CONDUIT TO OVERLOAD ALARM
OVERLOAD ALARM
EFFLUENT WEIR
EFFLUENT PIPE
DIRECTION OF ROTATION
EFFLUENT CHANNEL

PLAN

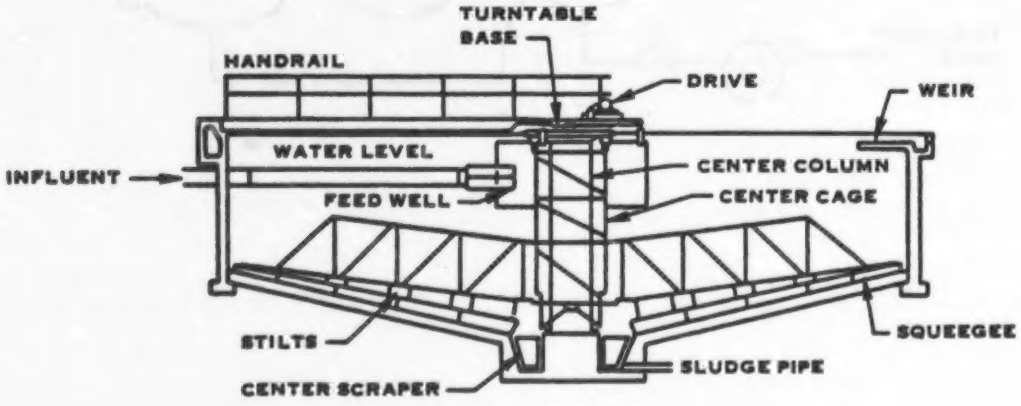

TURNTABLE BASE
HANDRAIL
DRIVE
WEIR
WATER LEVEL
INFLUENT
CENTER COLUMN
FEED WELL
CENTER CAGE
STILTS
SQUEEGEE
SLUDGE PIPE
CENTER SCRAPER

FIGURE VII-24. GRAVITY THICKENING

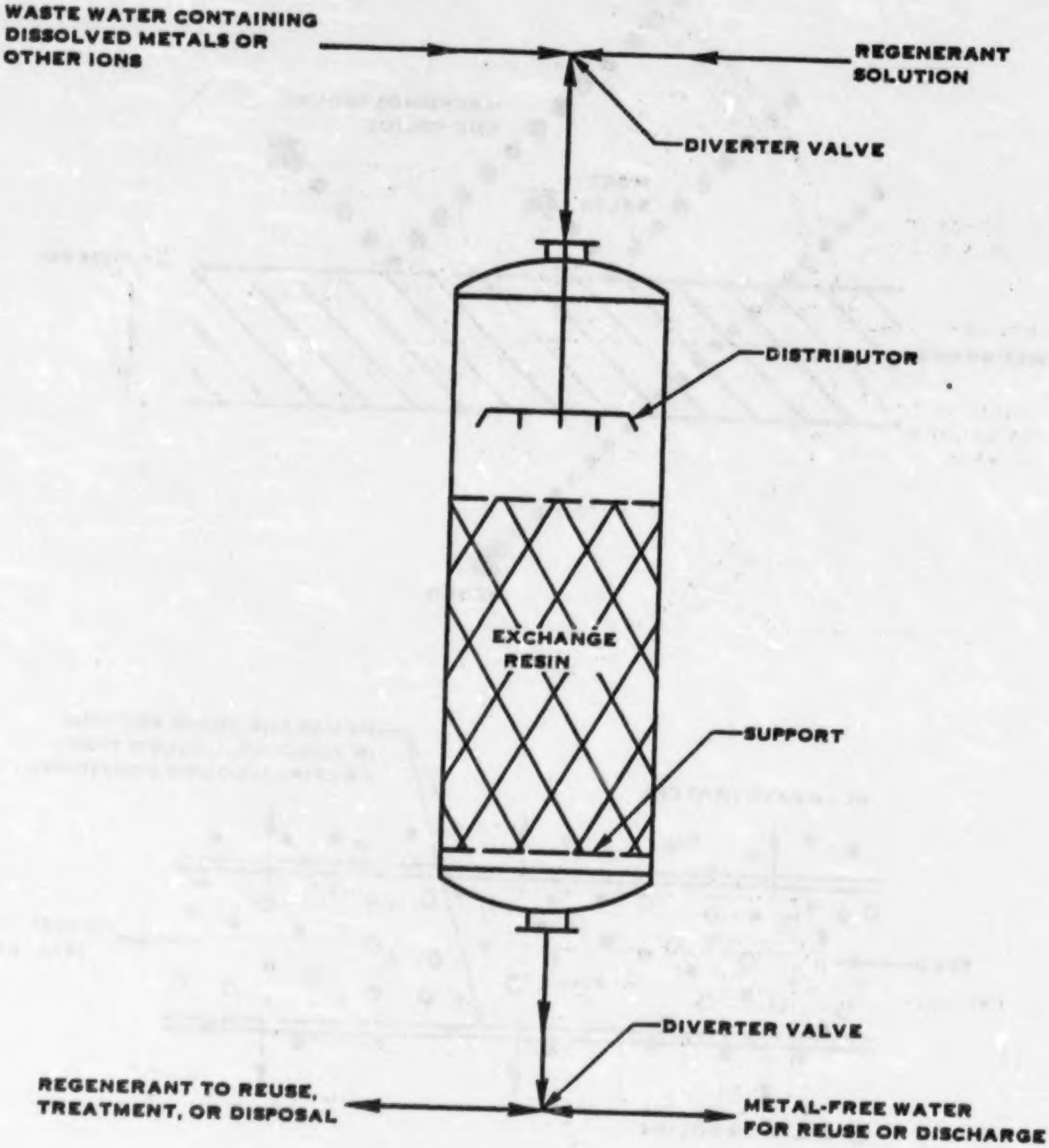

WASTE WATER CONTAINING DISSOLVED METALS OR OTHER IONS
REGENERANT SOLUTION
DIVERTER VALVE
DISTRIBUTOR
EXCHANGE RESIN
SUPPORT
DIVERTER VALVE
REGENERANT TO REUSE, TREATMENT, OR DISPOSAL
METAL-FREE WATER FOR REUSE OR DISCHARGE

FIGURE VII-25. ION EXCHANGE WITH REGENERATION

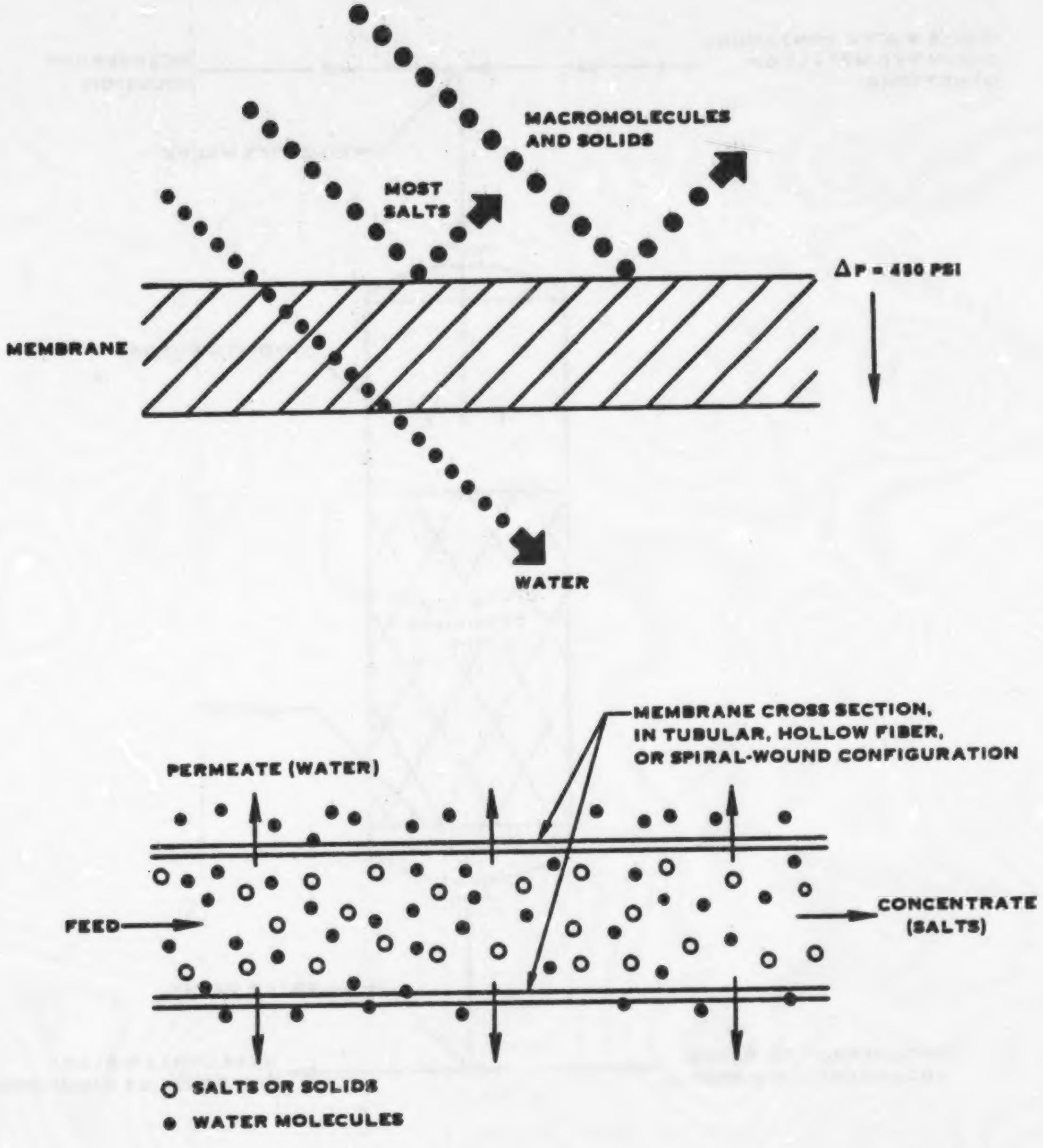
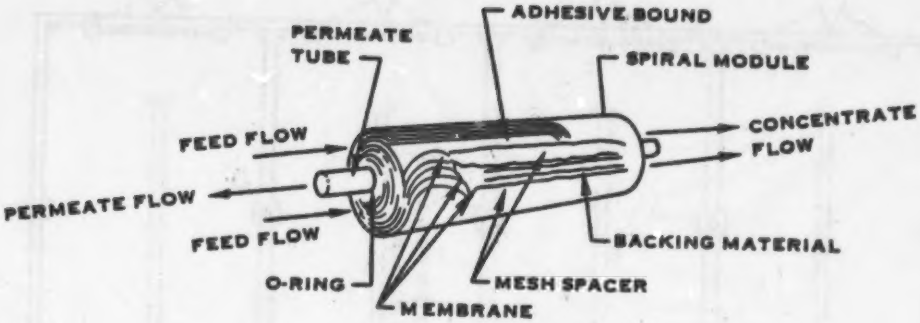
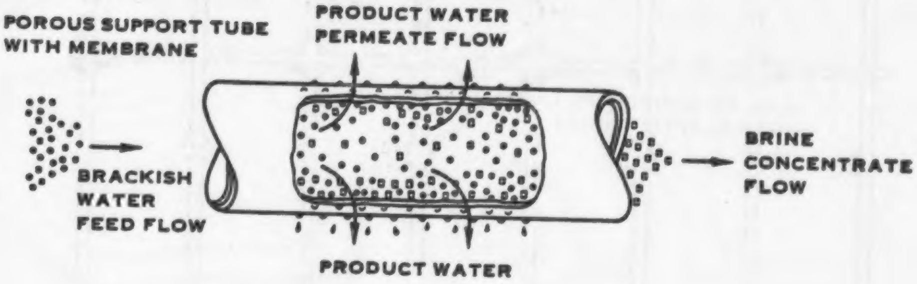

MACROMOLECULES AND SOLIDS
MOST SALTS
ΔP = 450 PSI
MEMBRANE
WATER
MEMBRANE CROSS SECTION, IN TUBULAR, HOLLOW FIBER, OR SPIRAL-WOUND CONFIGURATION
PERMEATE (WATER)
FEED
CONCENTRATE (SALTS)
○ SALTS OR SOLIDS
● WATER MOLECULES

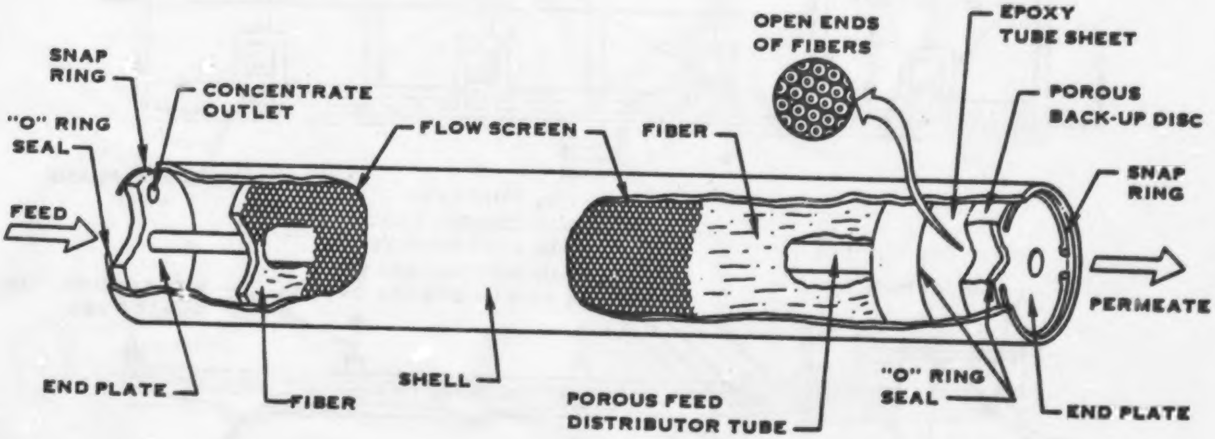
FIGURE VII-26. SIMPLIFIED REVERSE OSMOSIS SCHEMATIC


ADHESIVE BOUND
PERMEATE TUBE
SPIRAL MODULE
FEED FLOW
CONCENTRATE FLOW
PERMEATE FLOW
FEED FLOW
BACKING MATERIAL
O-RING
MESH SPACER
MEMBRANE

SPIRAL MEMBRANE MODULE

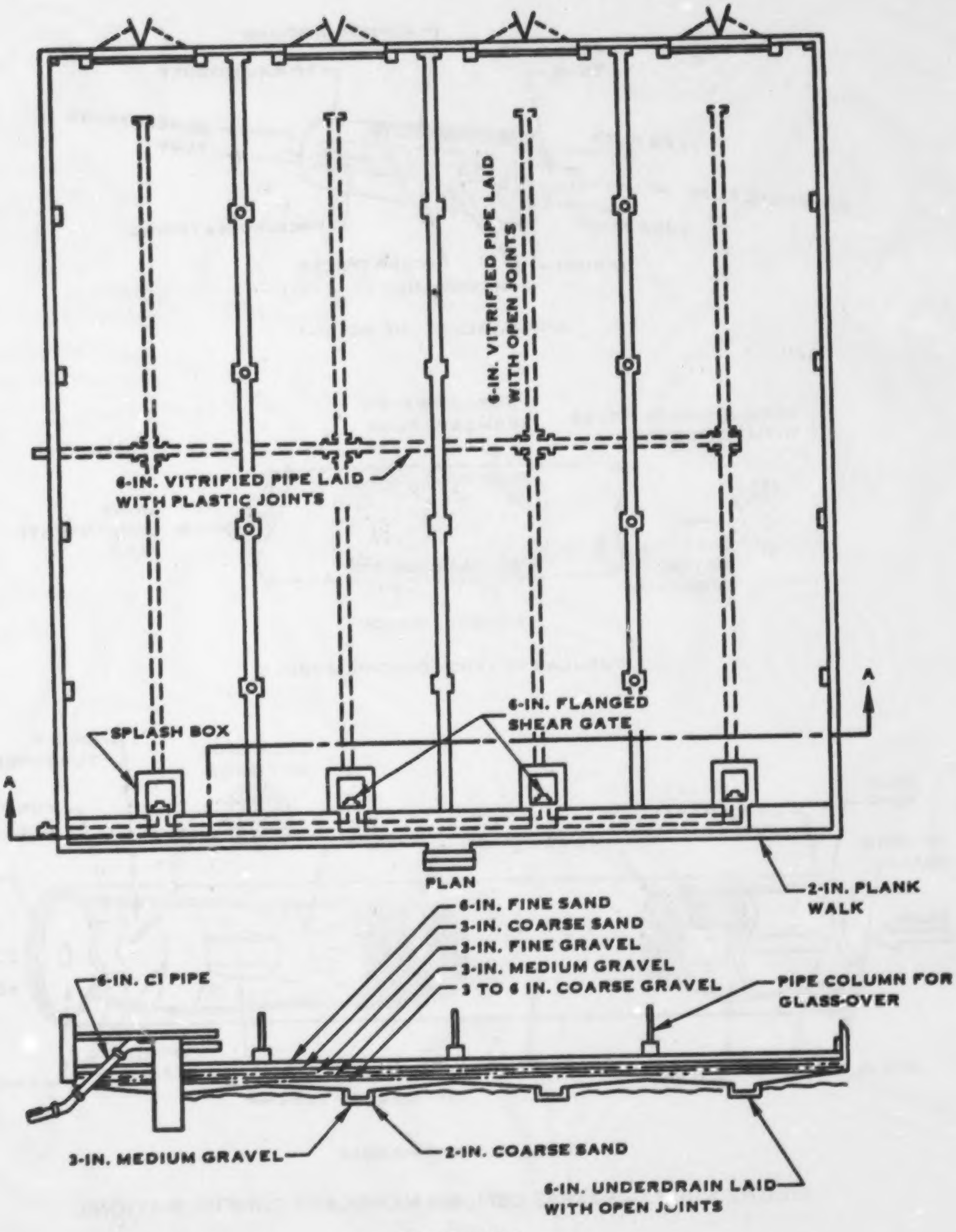

POROUS SUPPORT TUBE WITH MEMBRANE
PRODUCT WATER PERMEATE FLOW
BRACKISH WATER FEED FLOW
BRINE CONCENTRATE FLOW
PRODUCT WATER

TUBULAR REVERSE OSMOSIS MODULE


OPEN ENDS OF FIBERS
EPOXY TUBE SHEET
SNAP RING
CONCENTRATE OUTLET
POROUS BACK-UP DISC
"O" RING SEAL
FLOW SCREEN
FIBER
SNAP RING
FEED
PERMEATE
END PLATE
FIBER
SHELL
POROUS FEED DISTRIBUTOR TUBE
"O" RING SEAL
END PLATE

HOLLOW FIBER MODULE

FIGURE VII-27. REVERSE OSMOSIS MEMBRANE CONFIGURATIONS


6-IN. VITRIFIED PIPE LAID WITH OPEN JOINTS
6-IN. VITRIFIED PIPE LAID WITH PLASTIC JOINTS
A
A
6-IN. FLANGED SHEAR GATE
SPLASH BOX
2-IN. PLANK WALK
6-IN. FINE SAND
3-IN. COARSE SAND
3-IN. FINE GRAVEL
3-IN. MEDIUM GRAVEL
3 TO 6 IN. COARSE GRAVEL
6-IN. CI PIPE
PIPE COLUMN FOR GLASS-OVER
3-IN. MEDIUM GRAVEL
2-IN. COARSE SAND
6-IN. UNDERDRAIN LAID WITH OPEN JOINTS

PLAN

SECTION A-A

FIGURE VII-28. SLUDGE DRYING BED

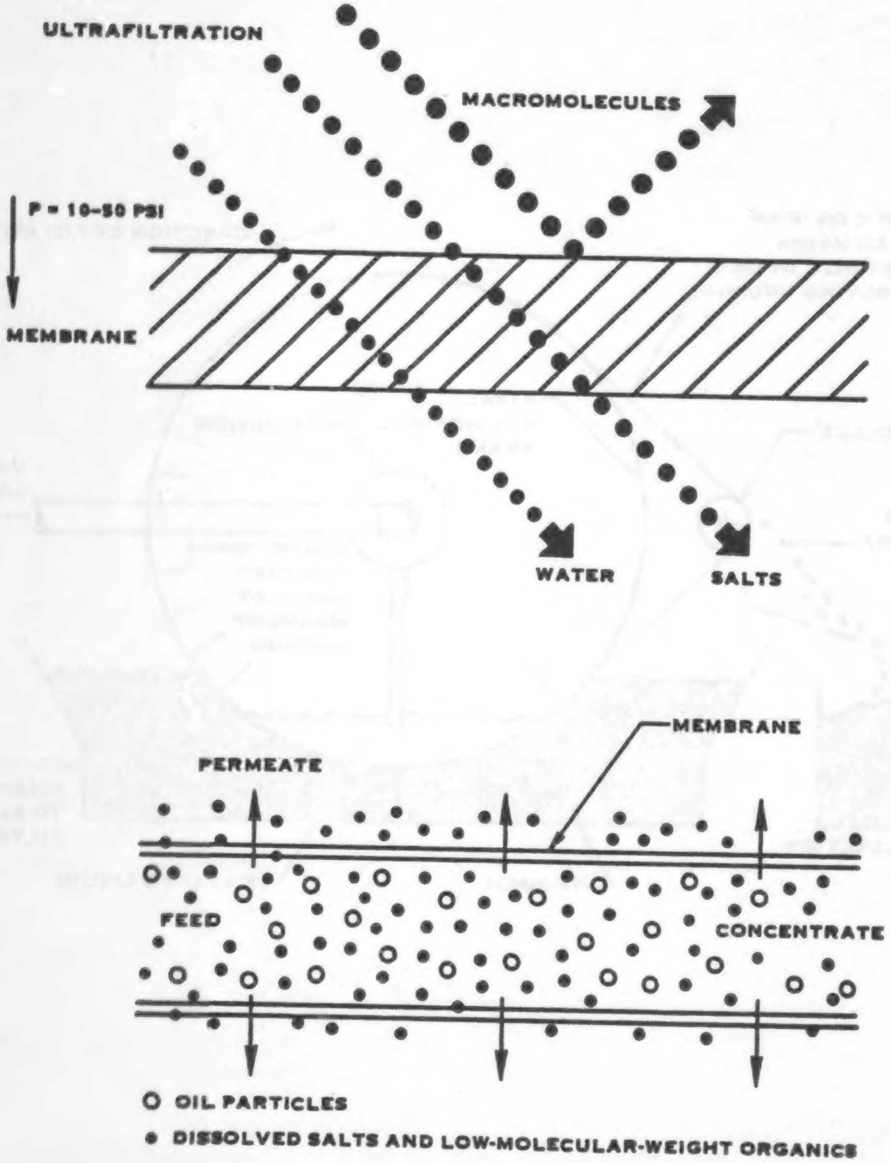

ULTRAFILTRATION
MACROMOLECULES
P = 10–50 PSI
MEMBRANE
WATER
SALTS
MEMBRANE
PERMEATE
FEED
CONCENTRATE
○ OIL PARTICLES
● DISSOLVED SALTS AND LOW-MOLECULAR-WEIGHT ORGANICS

FIGURE VII-29. SIMPLIFIED ULTRAFILTRATION FLOW SCHEMATIC

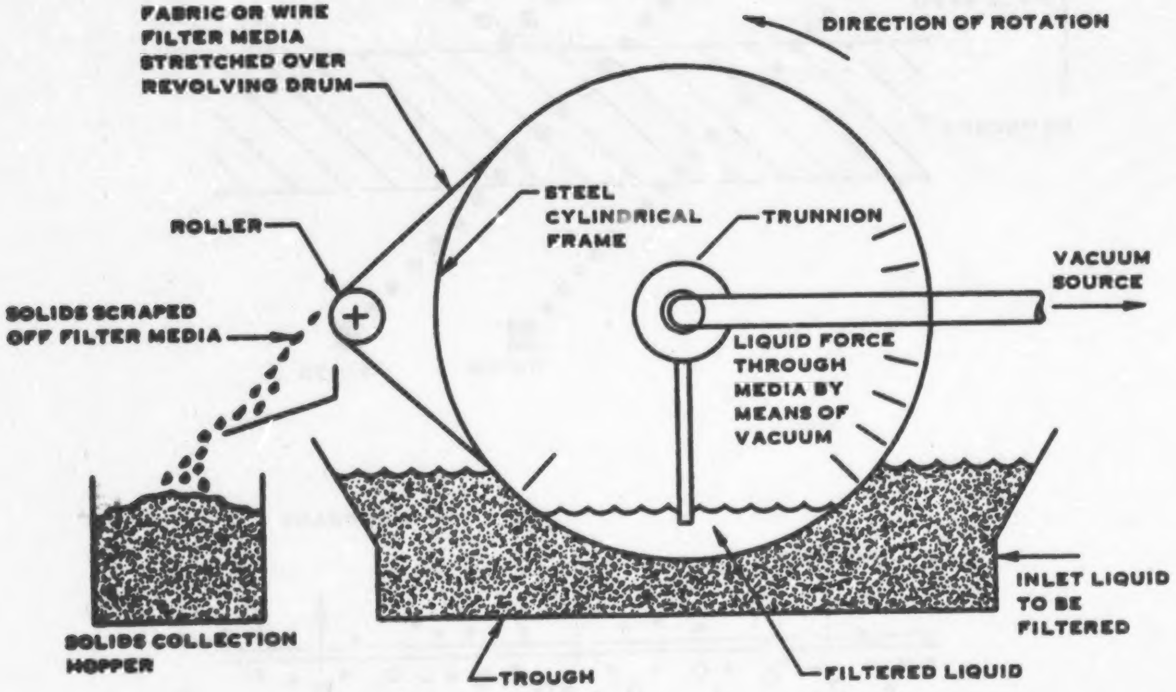

FABRIC OR WIRE FILTER MEDIA STRETCHED OVER REVOLVING DRUM
DIRECTION OF ROTATION
STEEL CYLINDRICAL FRAME
TRUNNION
ROLLER
VACUUM SOURCE
SOLIDS SCRAPED OFF FILTER MEDIA
LIQUID FORCE THROUGH MEDIA BY MEANS OF VACUUM
INLET LIQUID TO BE FILTERED
SOLIDS COLLECTION HOPPER
TROUGH
FILTERED LIQUID

FIGURE VII-30. VACUUM FILTRATION

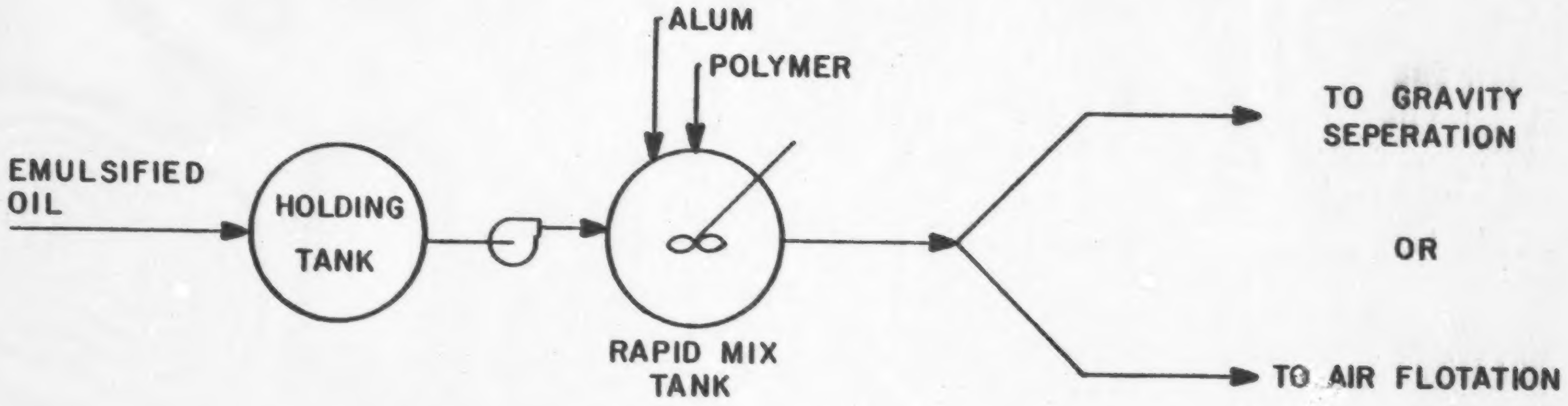

EMULSIFIED OIL
HOLDING TANK
ALUM
POLYMER
RAPID MIX TANK
TO GRAVITY SEPERATION
OR
TO AIR FLOTATION

Figure VII-31

FLOW DIAGRAM FOR EMULSION BREAKING WITH CHEMICALS

SECTION VIII

COST OF WASTEWATER CONTROL AND TREATMENT

This section presents estimates of the costs of implementing the major wastewater treatment and control technologies described in Section VII. These cost estimates, together with the estimated pollutant reduction performance for each treatment and control option presented in Sections IX, X, XI, and XII provide a basis for evaluating the options presented and identification of the best practicable control technology currently available (BPT), best available technology economically achievable (BAT), best demonstrated technology (BDT), and the appropriate technology for pretreatment. The cost estimates also provide the basis for the determination of the probable economic impact on the canmaking subcategory of regulation at different pollutant discharge levels. In addition, this section addresses nonwater quality environmental impacts of wastewater treatment and control alternatives, including air pollution, noise pollution, solid wastes, and energy requirements.

Briefly, the approach taken to estimate capital and annual costs was as follows: first, for each regulatory option, several flow rates were selected that covered the expected range in size of can manufacturing plants. Next, the characteristics of the influent to wastewater treatment were specified based on analytical data collected by the Agency from sampled plants (see Section V). These flow rates and compositions were used as input to a computer cost estimation model. Next, the cost data estimated by the model were tabulated and plotted as cost curves. Finally, the costs for each plant in the canmaking subcategory were estimated by applying for each regulatory option a specific plant's wastewater flow to the cost curves. These costs are the cost basis for the Agency's economic impact analysis for this subcategory.

CHANGES IN COSTS BETWEEN PROPOSAL AND PROMULGATION

Several substantive differences occurred in the cost assumptions used to develop costs for promulgation from those used at proposal. First, the raw wastewater characteristics used at proposal were based in most cases on maximum values or raw waste concentrations of the analytical data in the subcategory at a flow of 27,100 liters per hour. For promulgated costs, after reevaluating the data base and correcting errors, influent concentrations were based on the mean values of sampling data at a mean flow of 9,000 liters per hour. This revised base had a tendency to lower costs compared to those calculated at proposal,

Preceding page blank

due primarily to the decreased pollutant loading on the vacuum filter.

Second, oil removal costs at promulgation were based on an integrated technology set instead of a combination of independent technologies as used at proposal. The integrated set, which consisted of chemical emulsion breaking, dissolved air flotation (DAF) and oil skimming, tended to result in lower costs compared to the independent case since redundant equipment costs were excluded (e.g. tanks, pumps). Also, oil skimming, when integrated with DAF, was based on a belt skimmer instead of a more costly continuous oil skimmer. In addition, a comparative analysis was performed between proposal and promulgation to examine the cost tradeoff between ultrafiltration and the integrated technology set described above to accomplish oil removal. The results showed that the integrated technology costs were lower and were thus retained as the oil removal costs at promulgation.

Third, the "six-tenths" rule was used to extrapolate cost data to different size flows for proposed costs, while final costs were developed and plotted for seven separate model flow rates and characteristics yielding a more accurate estimate of compliance costs. This revised approach generally tended to lower final costs across the range of flows examined.

Fourth, costs for contract hauling of wastewater treatment sludge were not included at proposal. They are included in costs at promulgation. This tended to increase the final costs over the proposal costs.

Finally, several specific changes were made in many of the modules; these are addressed in the discussion of each module later in this section.

COST ESTIMATION METHODOLOGY

For the canmaking subcategory, cost estimation is accomplished using a computer model which accepts inputs specifying the treatment system to be estimated, chemical characteristics of the raw waste streams, flow rates and operating schedules. This model utilizes a computer-aided design of a wastewater treatment system containing modules that are configured to reflect the model wastewater treatment equipment at an individual plant. The model designs each module and then executes a costing routine that contains the cost data for each module. The capital and annual costs from the costing routine are combined with capital and annual costs for the other modules to yield the total costs for that regulatory option. The process is then repeated for each regulatory option.

Each module was developed by coupling theoretical design information from the technical literature with actual design data from operating plants. These data are used to design the component pieces of equipment in each module. Designing and estimating costs for each piece of equipment separately permits greater accuracy in the total estimated costs than if modules that included several pieces of equipment were the fundamental unit of costing. This approach closely reflects the way a plant would actually design and purchase its equipment. The resulting costs are thus more closely tied to the actual costs that would be incurred by the facility.

Overall Structure

The cost estimation model comprises two main parts: a material design portion and a costing portion. The material design portion uses input provided by the user to calculate design parameters for each module included in the treatment system. The design parameters are then used as input to the costing routine, which contains cost equations for each discrete component in the system. The structure of the program is such that the entire system is designed before any costs are estimated.

Throughout the program, the following pollutants or parameters are tracked:

- Flow
- Total suspended solids
- pH
- Temperature
- Acidity
- Aluminum
- Ammonia
- Antimony
- Arsenic
- Cadmium
- Chromium (trivalent)
- Chromium (hexavalent)
- Cobalt
- Copper
- Cyanide (amenable to chlorination)
- Cyanide (total)
- Fluoride
- Iron
- Lead
- Manganese
- Nickel
- Oil & Grease
- Phosphorus
- Selenium
- Silver
- Thallium
- Zinc

The overall logic flow of the computer programs is depicted in Figure VIII-1 (page 291). First, constants are initialized and certain variables such as the modules to be included, the system configuration, plant and wastewater flows, compositions, and entry points are specified by the user. Each module is designed utilizing the appropriate flow and composition data for influent streams. The design values are transmitted to the cost routine. The appropriate cost equations are applied, and the module costs and system costs are computed. Figures VIII-2 and VIII-3 (pages

292 and 293) depict the logic flow diagrams in more detail for the two major segments of the program.

System Input Data

Several data inputs are required to run the computer model. First, the treatment modules to be costed and their sequence must be specified. The sequence for each regulatory option is determined from the treatment technology diagrams shown in Section X. The hours of operation per day and number of days of operation per year is required. The flow values and characteristics must be specified for each wastewater stream entering the treatment system. These values will dictate the size and other parameters of components to be included.

These inputs are derived from actual data if costs are sought for actual plants. Where costs are developed for representative plants, flows and concentrations are derived from aggregated data. For development of costs for the canmaking subcategory, data from Section V were used.

Model Results

For a given plant, the model will generate comprehensive material balances for each parameter tracked in the system. It will also summarize design values for key equipment in each treatment module, and provide a tabulation of costs for each element in each module, module summaries, total equipment costs, and system capital and annual costs.

GENERAL COST FACTORS

Dollar Base - All costs are adjusted to first quarter 1982 dollars.

Cost Update Factors

Investment - Investment costs were updated using the EPA-Sewage Treatment Plant Construction Cost Index. The value of this index for the first quarter of 1982 is 414.0.

Operation and Maintenance Labor - The ENR Skilled Labor Wage Index is used to update the portion of O&M costs attributable to labor. The March 1982 value is 325.

Maintenance Materials - The producer price index published by the Department of Labor, Bureau of Statistics is used. The March 1982 value of this index is 276.5.

Chemicals - The Chemical Engineering Producer Price Index for industrial chemicals is used. This index is published biweekly in *Chemical Engineering* magazine. The March 1982 value of this index is 362.6.

Energy - Updating power costs is accomplished by using the price for the desired date for electricity and multiplying it by the energy requirements for the module in kwhr equivalents.

Annual Costs

Labor - A base labor rate for skilled labor of $9.00 per hour was used. To account for supervisory personnel, 15 percent of the labor rate was included. Plant overhead at 100 percent of the combined base and supervisory labor charges is also included.

The resulting composite labor rate used in this study is $21.00 per hour.

Operating Schedule - Two hundred and fifty days per year, 24 hours per day was assumed.

Energy - An electrical cost of 4.83 cents/kwhr (March, 1982) was assumed, based on the industrial cost derived from DOE's Monthly Energy Review.

System Costs

Engineering - This was assumed to be 15 percent of the total module cost.

Contractor's Fee - This was assumed to be 10 percent of the summed module cost.

Contingency - This was assumed at 10 percent of the summed module cost.

Taxes and Insurance - This was assumed at 1 percent of the total capital cost.

Monitoring - These costs are estimated at $120 per sample, which are in turn estimated according to the breakdown shown in Table VIII-1 (page 288).

Capital Recovery - These costs for recovery of committed capital may be calculated using a capital recovery factor, given by the following equation:

$$CRF = i + \frac{1}{(1+i)^n - 1}$$

where CRF = capital recovery factor
i = interest rate (%), and
n = period (in years) of amortization

For this analysis, an interest rate of 12 percent and a period of 10 years were used. This yields a CRF of 0.17698. This value is multiplied by the total capital investment to give the annual amortization charge.

TECHNOLOGY BASIS FOR COST ESTIMATION

Treatment technologies have been selected from among the larger set of available alternatives discussed in Section VII after considering such factors as raw waste characteristics, typical plant characteristics (e.g., location, production schedules, product mix, and land availability), and present treatment practices. Specific rationale for selection is addressed in Sections IX, X, XI, and XII. Cost estimates for each technology addressed in this section include investment costs and annual costs for depreciation, capital, operation and maintenance, and energy.

Options for existing sources and new sources were identified as the treatment alternatives for the canmaking subcategory. The technologies used, which were described in detail in Sections III and VII, include:

- Counterflow rinsing,
- Countercurrent cascade rinsing,
- Equalization,
- Chromium reduction,
- Chemical emulsion breaking,
- Dissolved air flotation,
- Oil skimming,
- Chemical precipitation-sedimentation,
- Vacuum filtration,
- Multimedia filtration,
- Contract hauling,
- Ultrafiltration, and
- Electrodialysis

The specific assumptions for each wastewater treatment module are listed under the subheadings to follow. Costs are presented as a function of influent wastewater flow rate except where noted in the unit process assumptions.

New source costs are based on the characteristics of a "normal" plant. The normal plant is a concept developed to aid in the estimation of new source costs and average plant characteristics. The production size of the normal was determined by summing the production of all plants in the subcategory and dividing by the total number of plants (696 million cans per year). Wastewater flow for the normal plant was assumed equal to the average production normalized flow for the subcategory and the raw waste characteristics equal to the average pollutant concentrations shown in Table V-11. This normal plant was also used for estimating pollutant reduction benefits and other factors in the following Sections.

Counterflow Rinsing

This technology is applied to product rinsing operations. It involves a number of spray rinse stages, with product and rinse water moving in opposite directions (more detail may be found in Sections III and VII). This allows for significantly reduced flow over single stage rinsing by reusing the rinse water from the stage 5 rinse as the stage 3 rinse.

The counterflow rinsing equipment and costs were evaluated against the modified countercurrent cascade rinsing costed at proposal and found to have nearly identical costs except for the $1000 allowance for installing a baffle. The previously developed cost module for countercurrent cascade rinsing was thus used to estimate the cost of counterflow rinsing.

Countercurrent Cascade Rinsing

The countercurrent cascade rinsing system used for estimating costs for existing plants in this subcategory at proposal was designed assuming that a tank for single stage rinse was already installed. The tank was converted to a two stage countercurrent operation by installing a baffle in the tank, recycle piping, an additional spray rinsing system, and an additional pump. The cost of the baffle was assumed to be constant at $1,000. A centrifugal pump, rated for the influent flow rate was assumed to be required. The spray rinsing system included additional spray nozzles, valves, and instrumentation (conductivity monitor, probe, controller, etc.). Installation costs were assumed to be 50 percent of the total equipment cost. Recycle piping costs at 20 percent and a retrofit allowance at 15 percent of the total installed equipment cost were also added.

The countercurrent cascade rinsing design used as a basis for new sources differs from the technology as applied in existing sources. An extended stage canwasher operation was used as an alternate basis for flow reduction since this represents for many plants a suitable tradeoff between achievable water conservation and the cost of additional equipment. Costs were developed for this technology by adding additional spray rinsing units. Additional piping, tankage, nozzles, and pumps were included to add three additional countercurrent cascade rinse stages to a conventional six stage canwasher.

Operation and maintenance costs were calculated assuming 5 percent of the plant annual operating hours as operating and maintenance labor and 2 percent of the capital cost as maintenance materials costs. The capital and annual costs for additional spray rinsing are presented in Figure VIII-4 (page 294) for existing sources. Costs for new source spray rinsing for countercurrent cascade rinsing are also shown in Figure VIII-4 (page 294).

Chromium Reduction

This technology can be applied to waste streams containing significant concentrations of hexavalent chromium. Chromium in this form will not precipitate until it has been reduced to the trivalent form. The waste stream is treated by addition of acid and gaseous SO_2 dissolved in water in an agitated reaction vessel. The SO_2 is oxidized to sulfate while reducing the chromium. The equipment required for this continuous stream includes an SO_2 feed system (sulfonator), an H_2SO_4 feed system, a reactor vessel and agitator, and a pump. The reaction pH is 2.5 and the SO_2 dosage is a function of the influent loading of hexavalent chromium. A conventional sulfonator is used to meter SO_2 to the reaction vessel. The mixer velocity gradient is 100 cm/sec/cm.

Annual costs are as follows:

(1) SO_2 feed system

--SO_2 cost at $0.11/kg ($0.25/lb)

--operation and maintenance labor requirements vary from 437 hrs/yr at 4.5 kg SO_2/day (10 lb SO_2/day) to 5,440 hrs/yr at 4,540 kg SO_2/day (10,000 lb SO_2/day)
--energy requirements may vary from 570 kwh/yr at 4.5 kg SO_2/day (10 lb SO_2/day) to 31,000 kwh/yr at 4,540 kg SO_2/day (10,000 lb SO_2/day)

(2) H_2SO_4 feed system

--operating and maintenance labor varies from 72 hrs/yr at 37.8 l/day (10 gpd) of 93 percent H_2SO_4 to 200 hrs/yr at 3,780 l/day (1,000 gpd)
--maintenance materials at 3 percent of the equipment cost
--energy requirements for metering pump and storage heating and lighting

(3) Reactor vessel and agitator

--operation and maintenance labor at 120 hrs/yr
--electrical requirements for agitator

The capital and annual costs for this technology are shown in Figure VIII-5 (page 294).

Equalization

Equalization tanks are of the vertical steel type with capacities which vary as a function of flow rate. The detention time is eight hours and the excess capacity is 20 percent. The tanks are fitted with agitators with a horsepower requirement of 0.006 kw/1,000 liters (.03 hp/1,000 gallons) of capacity to prevent sedimentation. A control system, valves, a pump, and piping are also included. The capital and annual costs are presented in Figure VIII-6 (page 296).

Chemical Emulsion Breaking

Chemical emulsion breaking involves the separation of relatively stable oil-water mixtures by addition of certain chemicals, in this case, alum and polymer. To determine the capital and annual costs, 400 mg/l of alum and 2 mg/l of polymer are assumed to be added to waste streams containing emulsified oils. The equipment included in the capital and annual costs for continuous operation are as follows:

- Chemical feed system
    1. Storage units
    2. Dilution tanks
    3. Conveyors and chemical feed lines
    4. Chemical feed pumps
- Rapid mix tank
    1. Tank
    2. Mixer
    3. Motor drive unit
- Flocculator Tank (retention time of 45 minutes)
- Pump

The stabilized oil-water mixture is then pumped to a flotation tank, which is discussed under dissolved air flotation below.

For the batch emulsion breaking unit, the following items are included:

- Sulfuric acid feed system
  1. Storage tanks or drums
  2. Chemical feed pumps
- Tank (retention time of 8 hours)
- Agitator
- Effluent water pump

In either mode, alum, polymer, and sulfuric acid (93 percent) costs were assumed to be \$0.257/kg (\$0.118/lb), \$4.95/kg (\$2.25/lb) and \$0.08/kg (\$0.037/lb), respectively. The breakpoint between batch and continuous modes is approximately 5,000 l/hr.

The capital and annual costs are presented in Figure VIII-7 (page 297).

Dissolved Air Flotation

Dissolved air flotation (DAF) is an oil removal method. It is designed to function as a stand-alone device, but may also be used in combination with emulsion breaking equipment to increase oil removal efficiency. The DAF system costs include a slop tank to allow for separation of the oil-water-air mixture leaving the DAF unit. The DAF system is typically followed by oil skimming to remove the oil-rich phase for disposal based on a continuous oil-water separator. However, when the two technologies are used in conjunction, oil skimming may be accomplished with a belt skimmer for relatively low oil removal rates (less than 50 gal/hr of oil), provided the oil-rich phase has formed a surface layer. The belt skimmer is located in the slop tank, whose retention time (4 hours) is assumed to be sufficient to allow the oily surface layer to form.

Capital costs were obtained from various vendors for package DAF units consisting of the following equipment:

- dissolved air flotation unit
  - o rectangular tank
  - o sludge auger and drive
  - o float skimmer and drive
  - o distributors
- recycle-pressurization pump
- air dissolution tank
- electrical equipment and instrumentation.

Costs for the slop tank, an influent pump, a sludge pump, a concrete slab and installation of the unit are also included.

Assumptions made in the design of the DAF system include:

- hydraulic loading = 1 gpm/ft^2
- oil concentration in effluent = 10 mg/l
- float composition: 10 wt percent oil and solids, 40 wt percent water, 50 wt percent air
- 25 percent of influent TSS settles in the unit; 65 percent emerges in the float
- installation time = 16 manhours

Operation and maintenance labor and process energy costs dominate annual costs, according to the vendors contacted. Therefore, material costs are assumed to be negligible. Operation of the DAF unit requires approximately 200 hr/yr labor regardless of unit size. Maintenance labor requirements are also assumed constant at 20 hr/yr. Energy requirements range from 15,700 kwhr/yr for a 10 gpm unit to 75,300 kwhr/yr for a 500 gpm unit.

The capital and annual costs for dissolved air flotation used in conjunction with oil skimming are shown in FIgure VIII-8 (page 297).

Oil Skimming

Oil skimming, when used in conjunction with DAF, includes the following equipment:

- belt skimmer
- Oil storage tank (sized for 2 weeks of storage)
- Recycle pump
- Oil discharge pump

The capital and annual costs of oil skimming for this subcategory are included with dissolved air flotation in Figure VIII-8 (page 298). The cost of oil skimming is estimated at approximately $18,500 capital cost and $7,500 total annual cost.

Chemical Precipitation

Quicklime (CaO) or hydrated lime [$Ca(OH)_2$] can be used to precipitate toxic and other metals. Hydrated lime is commonly used for wastewaters with low lime requirements since the use of slakers, required for quicklime usage, is practical only for large-volume application of lime. Due to the low lime dosage requirements in this subcategory, hydrated lime is used for costing. The lime dosage requirements were determined by the model using specific influent characteristics and flow derived from wastewater data for representative canmaking operations.

The following equipment was included in the determination of capital and annual costs based on continuous operation:

- Lime feed system
    1. Storage units (sized for 30-day storage)
    2. Dilution tanks (five minutes average retention)
    3. Feed pumps
- Rapid mix tank (detention time of five minutes; mixer velocity gradient is 300/sec)
- Clarifier (overflow rate is 7.3 lph/m^2 (20.8 gph/ft^2); underflow solids is 3 percent)
    1. Sludge rakes
    2. Skimmer
    3. Weirs
- Sludge pump

The model assumes that a 10 percent excess of lime is used, that the final pH is 9.0, and the effluent pollutant concentrations are based on the CMDB L&S treatment effectiveness values.

Batch operation assumes a two fiberglass or steel tank system (if additional capacity is required, tanks are added in pairs) with one lime feed system (includes one agitated mixing tank with hydrated lime added manually in 22.7 kg (50 lb) bags for every two tanks), a sludge pump for up to four tanks, and a simple control system. A lime storage shed is included for lime addition rates ≥ 90.7 kg/batch (200 lb/batch).

O&M costs for the continuous system are for operating and maintenance labor for the clarifier and lime feed system, and the cost for chemicals, maintenance materials, and energy. For the batch mode, operational labor is assumed at one-half hour per batch for lime addition up to 90.7 kg/batch (200 lb/batch) and one hour per batch for additional rates above 90.7 kg/batch (200 lb/batch). Maintenance labor is constant for the batch system at 52 hours per year (one hour/week). Lime is $47.30/kkg ($43/ton) in 22.7 kg (50 lb) bags and energy requirements and maintenance materials are negligible.

The operating mode is selected based on an annualized cost comparison assuming a 1,200 mg/l lime dosage. Three minor changes were made to this module between proposal and promulgation. First, the maximum volume for a single batch reactor tank was increased from 10,000 gallons to 25,000 gallons. Second, the single batch duration was reduced from 12 hours to 8 hours. Third, the minimum cost for a batch lime feed system was reduced to $2,500 from $16,000. These changes were made to more accurately reflect actual practice at plants. The net effect of each is to decrease capital costs. The capital and annual costs are presented in Figure VII-9 (page 299).

Multimedia Filtration

Multimedia filtration is used as a wastewater treatment polishing device to remove suspended solids not removed in previous treatment processes. The filter beds consist of graded layers of gravel, coarse anthracite coal, and fine sand. The equipment used to determine capital and annual costs are as follows:

- Influent storage tank sized for one backwash volume
- Gravity flow, vertical steel cylindrical filters with media (anthracite, sand, and garnet)
- Backwash tank sized for one backwash volume
- Backwash pump to provide necessary flow and head for backwash operations
- Piping, valves, and a control system

The hydraulic loading rate is 63.2 lph/m² (180 gph/ft²) and the backwash loading is 252.8 lph/m² (720 gph/ft²). The filter is backwashed once per 24 hours for 10 minutes. The backwash volume is provided from the stored filtrate. The backwash stream is recycled to the clarifier. The capital and annual costs are shown in Figure VIII-10 (page 300).

Effluent pollutant concentrations are based on the LS&F treatment effectiveness data in Table VII-21.

Ultrafiltration

The ultrafiltration process employs a semipermeable polymeric membrane to remove colloidal material from a wastewater. In contrast to multimedia filtration, ultrafiltration does not operate intermittently, i.e., retained materials are continuously rather than periodically removed.

The equipment costed for this process includes:

- Membrane modules
- Equalization tank
- Process tank
- Feed pump
- Recirculation pump
- Piping

- Electrical and instrumentation

A flux rate of 0.51 lph/m² (1.46 gph/ft²) is applied in the tubular module.

Operation and maintenance labor is assumed to be negligible for this module. Chemical costs include cleaning solution, caustic, and acid for pH control. Maintenance materials primarily include replacement of filter membranes, which are estimated to have a two year life. The capital and annual costs for this technology are presented in Figure VIII-11 (page 301).

Vacuum Filtration

The underflow from the clarifier is routed to a rotary precoat vacuum filter, which dewaters the mostly hydroxide sludge (it also includes calcium fluoride precipitate) to a cake of 20 percent dry solids. The filtrate is recycled to the rapid mix tank as seed material for sludge formation.

The capital costs for the vacuum filter include the following:

- Vacuum filter with precoat but no sludge conditioning
- Housing
- Pump

The yield from the filter is assumed at 0.126 kg/hr/m² (3 lb/hr/ft²) with a solids capture of 95 percent. Housing for the filter is required. Two changes were made to this module after proposal. First, the housing costs were modified to account only for the area required by the vacuum filter and peripheral equipment. Second, the operating schedule was reduced to 8 hours per day. At proposal, this schedule was equivalent to the number of hours the plant operated. Costs are presented in Figure VIII-12 (page 302).

Electrodialysis

Water to be used in rinsing operations in a canwasher may require treatment prior to use to remove dissolved solids. One process currently in use at a can manufacturing facility to reduce dissolved solids levels is electrodialysis.

As shown in Figure VIII-13 (page 303), electrodialysis units consist of alternating cationic and anionic membranes arranged between two electrically charged plates. Due to the different charges on the plates, cations and anions will tend to migrate in opposite directions. Each alternating membrane allows passage of only one type of ion. Thus, a solution concentrated with ions will accumulate in every other chamber. The result is an ion concentrated stream (brine) and an ion depleted stream suitable for use in a canwasher.

The amount of electricity required, which accounts for a significant portion of the annual costs, is a strong function of the ion concentration. Thus electrodialysis is most suited for dilute solutions.

The electrodialysis process can be operated either continuously or on a batch basis (which involves recirculation of the product stream). Pretreatment of the incoming water (e.g., filtration, aeration) may be required to minimize membrane fouling, depending on the feed characteristics. However, it is unlikely to be necessary for the application discussed here since the source water should be relatively pure.

The required capacity of an electrodialysis plant can be expressed as the number of stages and the membrane area per stage. The number of stages is determined from the desired reduction in dissolved solids and the area required is determined by the influent flow rate.

Direct capital costs include the costs for purchase and installation of the electrodialysis equipment and storage for the feed and product streams. System capital costs include engineering, contingency and contractor's fee, which are estimated at 37.5 percent of the total direct capital costs. Total capital costs are presented in Figure VIII-14 (page 304) as a function of flow rate. These costs are based on one plant's reported investment cost for installation of a 46,000 gallon per day electrodialysis unit reducing solids from 700 mg/l to 120 mg/l. The unit included necessary pretreatment, storage of feed and product, and pumping. The curve was developed for other flow rates from the "six tenths" rule, where

$$\begin{pmatrix}\text{Installed}\\ \text{Cost}\end{pmatrix}_{\text{Plant B}} = \begin{pmatrix}\text{Installed}\\ \text{Cost}\end{pmatrix}_{\text{Plant A}} \times \left(\frac{\text{Flow rate A}}{\text{Flow rate B}}\right)^{0.6}$$

Direct annual costs are derived from an EPA electrodialysis demonstration unit. Based on a flow of 216,000 gpd, these costs include:

	$/1,000 gal
Power	1.35
Operating Labor	0.10
Maintenance labor	0.23
Membrane Replacement	0.12
Filter Replacement	0.06
Total	1.86

At different flows these costs (except for power costs) were adjusted downward slightly to reflect economies of scale. The power cost/1000 gal remained the same since this requirement should be directly proportional to the flow. To calculate total annualized costs, amortization at 17.7 percent and taxes and insurance at 1 percent of the total capital investment were added to the direct annual costs. The total annualized costs are shown as a function of flow rate in Figure VIII-15 (page 305).

Contract Hauling

This module, which was not included at proposal, provides for removal of sludges and oils to a nonhazardous disposal site. The cost is a strong function of the distance to the disposal site. A 50-mile round trip was assumed. This results in a disposal cost of $0.40 per gallon and is shown in Figure VIII-16 (page 306).

SYSTEM COST DEVELOPMENT

Options considered for existing and new sources were costed as follows:

Option A. This option includes chromium reduction, equalization, chemical emulsion breaking, dissolved air flotation, oil skimming, lime precipitation and sedimentation, vacuum filtration, and contract hauling. A production normalized flow of 215 l/1000 cans and individual plant data along with the costs displayed in Figures VIII-17 and VIII-18 (pages 307 and 308) were used to estimate compliance costs for BPT and PSES-O.

Option B. This option for end-of-pipe treatment is the same as for option A. In addition costs for counterflow rinsing (from Figure VIII-4) were combined with the end-of-pipe costs, and are displayed in Figures VIII-19 and VIII-20 (pages 309 and 310). A production normalized flow of 83.9 l/1000 cans and individual plant data along with the costs displayed in Figures VIII-19 and VIII-20 were used to estimate compliance costs for the promulgated BAT and PSES.

The normal plant characteristics were used to evaluate additional cost options. Compliance costs for these options are displayed in Table X-5 (page 335) and were based on the unit cost curves displayed in this Section.

Option C. This option includes option B in-process costs and adds polishing filtration to the end-of-pipe treatment.

Option D. This option included option B in-process costs and added ultrafiltration to the end-of-pipe treatment. This option was not re-evaluated for costing after proposal.

Option E. This option includes additional flow reduction achieved by including additional spray rinse units to option B in-process and end-of-pipe costs. A production normalized flow of 63.6 l/1000 cans along with the unit costs were used to estimate compliance costs for the promulgated new source standards. They overstate the costs for a new source plant because alternatively a plant can redesign a six stage conventional canwasher to achieve adequate flow reduction.

Option F. This option includes option E costs and adds polishing filtration to the end-of-pipe treatment.

Treatment In Place

The costs shown on the figures are greenfield costs that do not account for equipment that plants may already have in place. When costs are computed for an actual plant that has some of the equipment already installed, that cost component must be subtracted from the total module cost before adding subsidiary costs (costs such as engineering or contingency added at the system level as a percentage of the installed equipment cost).

Following proposal, treatment in place at canmaking plants was reevaluated. This information along with the costs presented in this section were used for calculating compliance costs for each plant for each selected treatment option and summed. Results of these calculations are presented in Table X-5 (page 335). These costs were then used for the economic impact analysis.

NONWATER QUALITY ENVIRONMENTAL ASPECTS

Nonwater quality aspects including energy requirements of all of the wastewater treatment technologies described in Section VII are summarized in Tables VIII-2 and VIII-3 (pages 289 and 290). General energy requirements are listed, the impact on environmental air and noise pollution is noted, and solid waste generation characteristics are summarized. The treatment processes are divided into two groups, wastewater treatment processes in Table VIII-2, and sludge and solids handling processes in Table VIII-3.

Energy Aspects

Energy aspects of the wastewater treatment processes are important because of the impact of energy on natural resources and the economy. Based on dcp information, the EPA determined a current energy consumption of 4,051 million kwhr/yr for canmaking operations in the subcategory, and 3.21 million kwhr/yr for wastewater treatment system operation. The energy requirements for the Option A (BPT) technology for direct dischargers is approximately 0.76 million kwhr/yr. Due to the reduction in wastewater flow, the BAT technology for direct dischargers should only require approximately 0.30 million kwhr/yr. The energy requirements for PSES technology for indirect dischargers is estimated to be 7.92 million kwhr/yr. A new source normal plant wastewater treatment system would add 0.075 million kwhr/yr to the energy requirement.

The energy requirements for the wastewater treatment options for the subcategory are generally low. When compared to the total plant energy usage, the wastewater treatment processes contribute less than 1.0 percent to the overall energy usage.

Other Environmental Aspects

It is important to consider the impact of each treatment process on water scarcity; air, noise, and radiation; and solid waste pollution of the environment to preclude the development of an adverse environmental impact.

Consumptive Water Loss. Where evaporative cooling mechanisms are used, water loss may result and contribute to water scarcity problems, a concern primarily in arid and semi-arid regions. These treatment options do not require substantial evaporative cooling and recycling which would cause a significant consumptive water loss.

Air Pollution. In general, none of the wastewater handling and treatment processes considered for this subcategory cause air pollution problems. For the precipitation of hexavalent chromium using SO_2 as a reducing agent, the potential exists for the evolution of SO_2 as a gas. However, proper design of the treatment tanks and proper pH control eliminates this problem. Incineration of waste oil lubricants could cause air pollution problems which need to be controlled by suitable scrubbers or precipitators, as well as proper incinerator operation and maintenance. The wastewater treatment sludges are not generally amenable to incineration because of their high noncombustible solids content.

Noise and Radiation. None of the wastewater treatment processes cause objectionable noise levels and none of the treatment processes has any potential for radiation hazards.

Solid Waste. Costs for wastewater treatment sludge handling were included in the costing analysis performed for the subcategory. To estimate the amount of wastewater treatment sludge produced as a result of the treatment technologies, a computer program is used. This program takes into account the amount of each pollutant element in the sludge at each treatment level given in Tables X-1 and XI-1 (pages 331 and 347). A 20 percent solids content of the sludge and a 10 percent excess of lime are the essential calculation parameters. For new sources a normal plant is used as the basis for cost estimating.

The lime precipitation and settling technology produces a sludge with a high solids content, consisting of calcium salts, toxic metals (chromium, copper, nickel and zinc), and other metals (aluminum and manganese) and a high pH. When this waste stream is subjected to the RCRA hazardous waste criteria, it is judged to be nonhazardous and therefore no hazardous waste disposal costs are attributed to disposal of the sludge.

Spent lubricating oil waste is also generated by canmaking plants and is generally disposed of in a landfill or reclaimed by contract waste haulers. Based upon dcp data, the quantity of this spent lubricant is estimated to be 595,000 kg/yr (270,000 lbs/yr) for a normal plant. Since the spent lubricant is considered to be nonhazardous under RCRA criteria, there are no RCRA related costs attributed to the disposal of this material.

TABLE VIII-1
WASTEWATER SAMPLING FREQUENCY

Wastewater Discharge (Liters Per Day)	Sampling Frequency
0 - 37,850	Once per month
37,851 - 189,250	Twice per month
189,251 - 378,500	Once per week
378,501 - 946,250	Twice per week
946,250+	Three times per week

TABLE VIII-2

NONWATER QUALITY ASPECTS OF WASTEWATER TREATMENT

PROCESS	ENERGY REQUIREMENTS			NONWATER QUALITY IMPACT			
	Power kwh / 1000 liters	Fuel	Energy Use	Air Pollution Impact	Noise Pollution Impact	Solid Waste	Solid Waste Concentration % Dry Solids
Chemical Reduction	1.0	—	Mixing	None	None	None	—
Skimming	0.01-.3	—	Skimmer Drive	None	None	Concentrated	5-50 (oil)
Clarification	0.1-3.2	—	Sludge Collector Drive	None	None	Concentrated	1-10
Flotation	1.0	—	Recirculation Pump, Compressor, Skim	None	None	Concentrated	3-5
Chemical Oxidation by Chlorine	0.3	—	Mixing	None	None	None	—
Oxidation by Ozone	0.5-5.0	—	Mixing Ozone Generation	None	None	None	—
Chemical Precipitation	1.02	—	Flocculation Paddles, Mixers	None	None	Concentrated	1-10
Sedimentation	0.1-3.2	—	Sludge Collector Drive	None, Possible H_2S Evolution	None	Concentrated	1-3
Deep Bed	0.10	—	Head, Backwash Pumps	None	None	Concentrated	Variable
Ion Exchange	0.5	—	Pumps	None	Not Objectionable	None	N/A
Adsorption	0.1	—	Pumps, Evaporate During Regeneration	None	None	None/Waste Carbon	40
Evaporation	—	2.5*	Evaporate Water	None	None	Concentrated/ Dewatered	50-100
Reverse Osmosis	3.0	—	High Pressure Pump	None	Not Objectionable	Dilute Concentrate	1-40
Ultrafiltration	1.25-3.0	—	High Pressure Pump	None	Not Objectionable	Dilute Concentrate	1-40
Membrane Filtration	1.25-3.0	—	High Pressure Pump	None	Not Objectionable	Dilute Concentrate	1-40
Electrochemical Chromium Reduction	0.2-0.8	—	Rectifier, Pump	None	None	Concentrated	1-3
Electrochemical Chromium Regeneration	2.0	—	Regeneration, Pump	None	None	None	—

* 10^6 BTU/1,000 liters

TABLE VIII-3

NONWATER QUALITY ASPECTS OF SLUDGE AND SOLIDS HANDLING

PROCESS	ENERGY REQUIREMENTS			NONWATER QUALITY IMPACT			
	Power kwh / ton dry solids	Fuel kwh / ton dry solids	Energy Use	Air Pollution Impact	Noise Pollution Impact	Solid Waste	Solid Waste Concentration % Dry Solids
Sludge Thickening	29-930	—	Skimmer, Sludge Rake Drive	None	None	Concentrated	4-27
Pressure Filtration	21	—	High Pressure Pumps	None	None	Dewatered	25-50
Sand Bed Drying	—	35	Removal Equipment	None	None	Dewatered	15-40
Vacuum Filter	16.7-66.8	—	Vacuum Pump, Rotation	None	Not Objectionable	Dewatered	20-40
Centrifugation	0.2-98.5	—	Rotation	None	Not Objectionable	Dewatered	15-50
Landfill	—	20-980	Haul, Landfill 1-10 Mile Trip	None	None	Dewatered	N/A
Lagooning	—	36	Removal Equipment	None	None	Dewatered	3-5

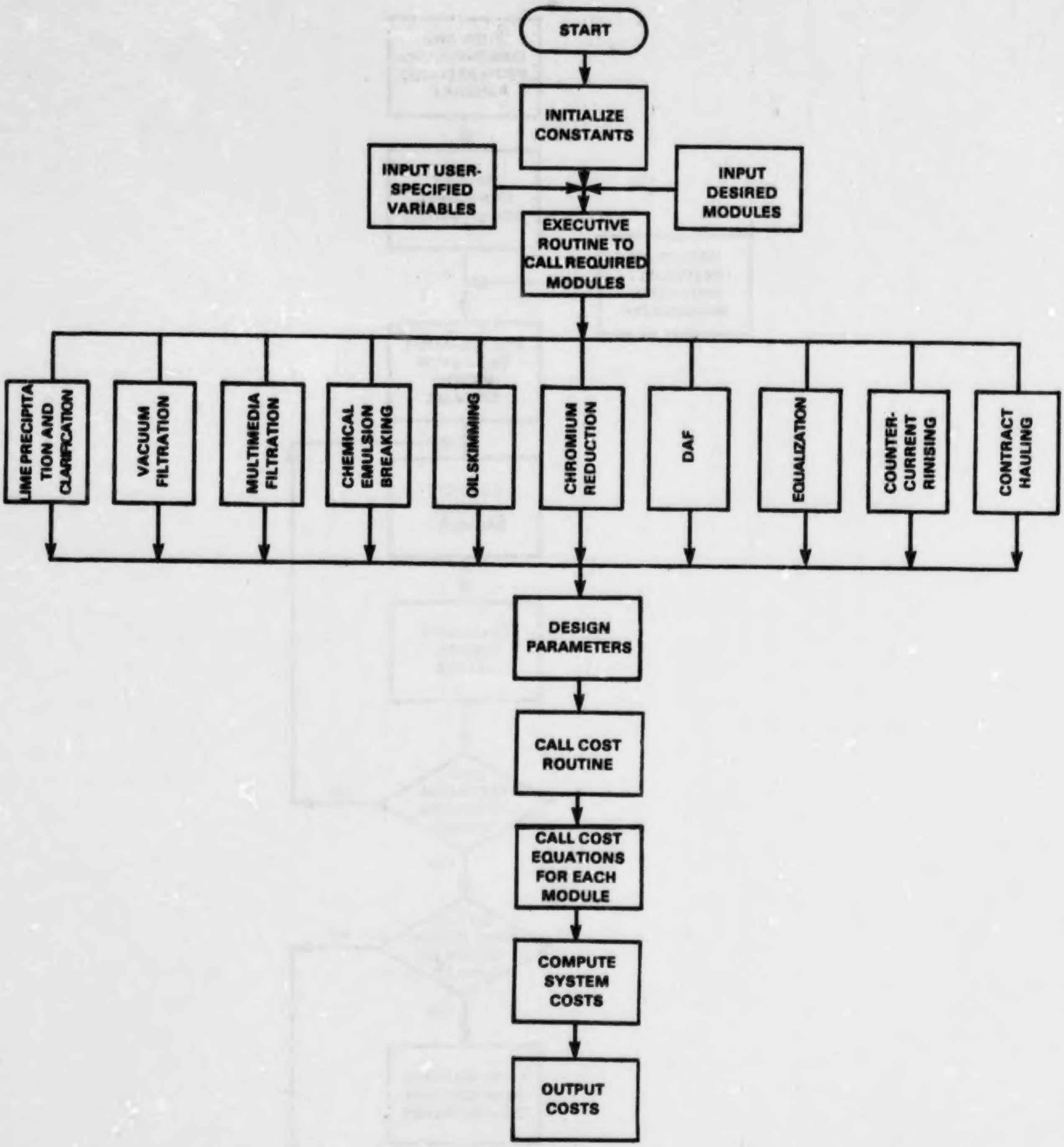

START
INITIALIZE CONSTANTS
INPUT USER-SPECIFIED VARIABLES
INPUT DESIRED MODULES
EXECUTIVE ROUTINE TO CALL REQUIRED MODULES
LIME PRECIPITATION AND CLARIFICATION
VACUUM FILTRATION
MULTIMEDIA FILTRATION
CHEMICAL EMULSION BREAKING
OIL SKIMMING
CHROMIUM REDUCTION
DAF
EQUALIZATION
COUNTER-CURRENT RINISING
CONTRACT HAULING
DESIGN PARAMETERS
CALL COST ROUTINE
CALL COST EQUATIONS FOR EACH MODULE
COMPUTE SYSTEM COSTS
OUTPUT COSTS

FIGURE VIII-1. GENERAL LOGIC DIAGRAM OF COMPUTER COST MODEL

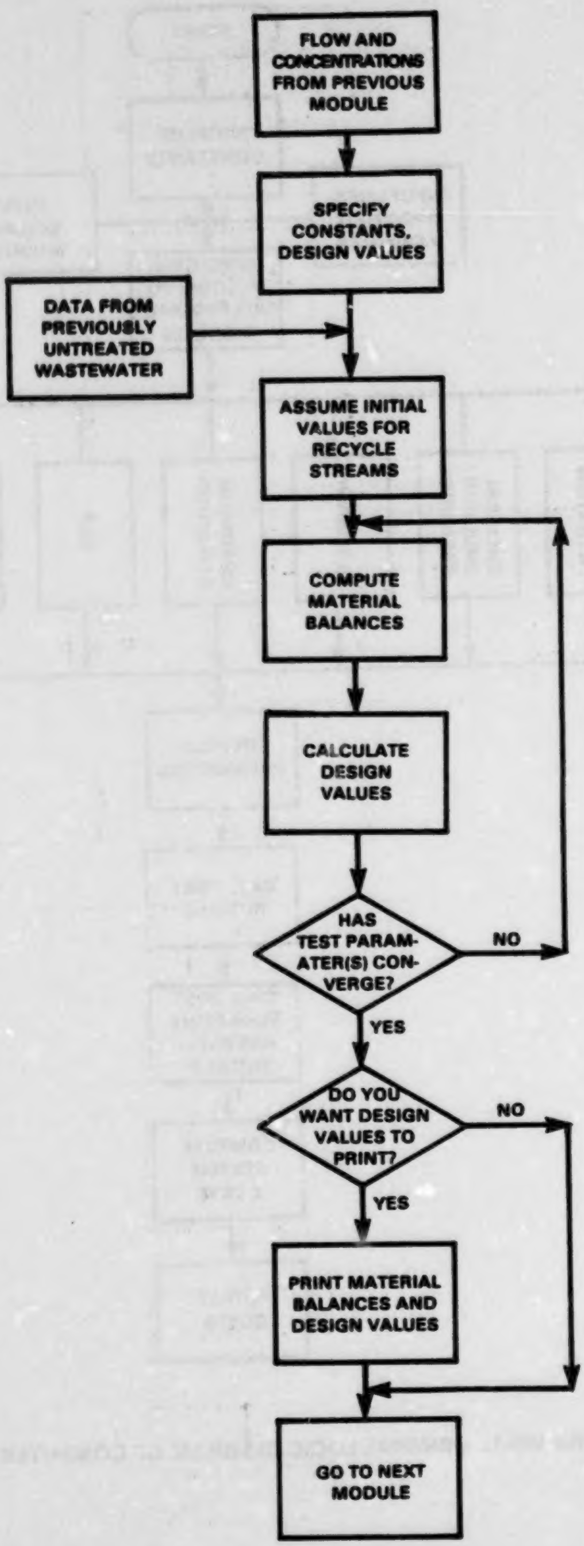

FLOW AND CONCENTRATIONS FROM PREVIOUS MODULE
SPECIFY CONSTANTS, DESIGN VALUES
DATA FROM PREVIOUSLY UNTREATED WASTEWATER
ASSUME INITIAL VALUES FOR RECYCLE STREAMS
COMPUTE MATERIAL BALANCES
CALCULATE DESIGN VALUES
HAS TEST PARAMATER(S) CONVERGE?
NO
YES
DO YOU WANT DESIGN VALUES TO PRINT?
NO
YES
PRINT MATERIAL BALANCES AND DESIGN VALUES
GO TO NEXT MODULE

FIGURE VIII-2. LOGIC DIAGRAM OF MODULE DESIGN PROCEDURE

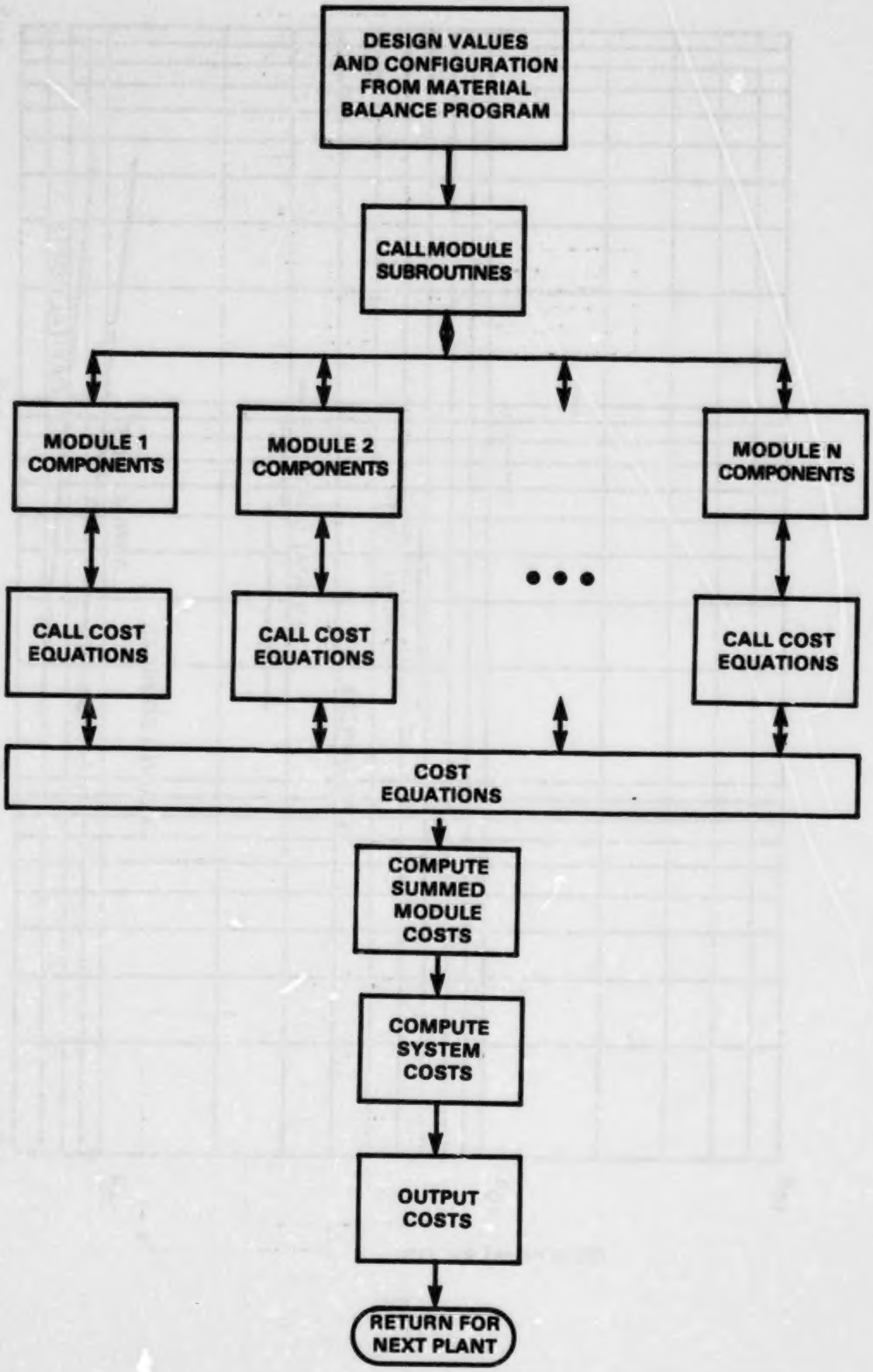

DESIGN VALUES AND CONFIGURATION FROM MATERIAL BALANCE PROGRAM
CALL MODULE SUBROUTINES
MODULE 1 COMPONENTS
MODULE 2 COMPONENTS
MODULE N COMPONENTS
CALL COST EQUATIONS
CALL COST EQUATIONS
CALL COST EQUATIONS
COST EQUATIONS
COMPUTE SUMMED MODULE COSTS
COMPUTE SYSTEM COSTS
OUTPUT COSTS
RETURN FOR NEXT PLANT

FIGURE VIII-3. LOGIC DIAGRAM OF THE COSTING ROUTINE

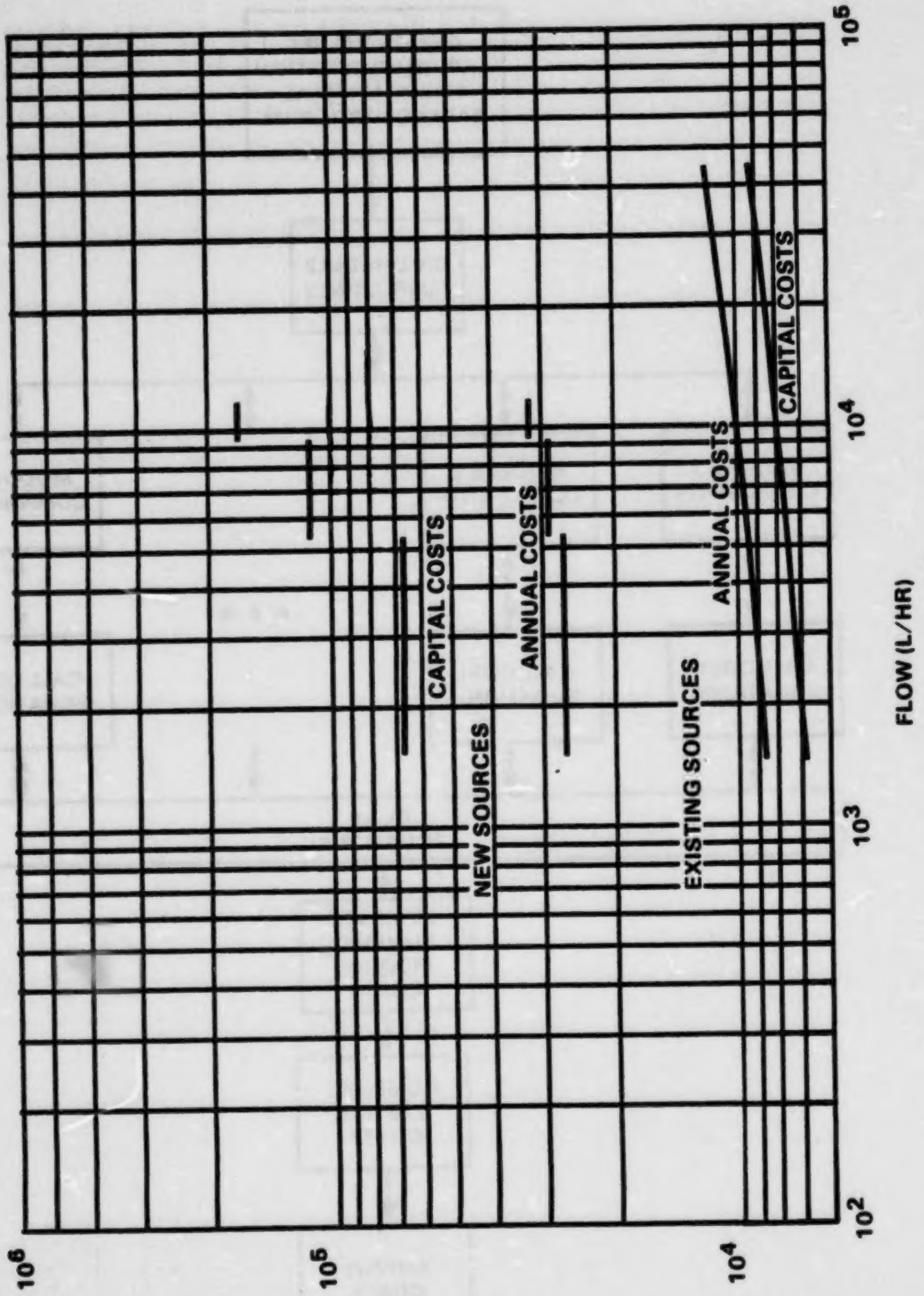


FIGURE VIII-4. COSTS FOR SPRAY RINSING

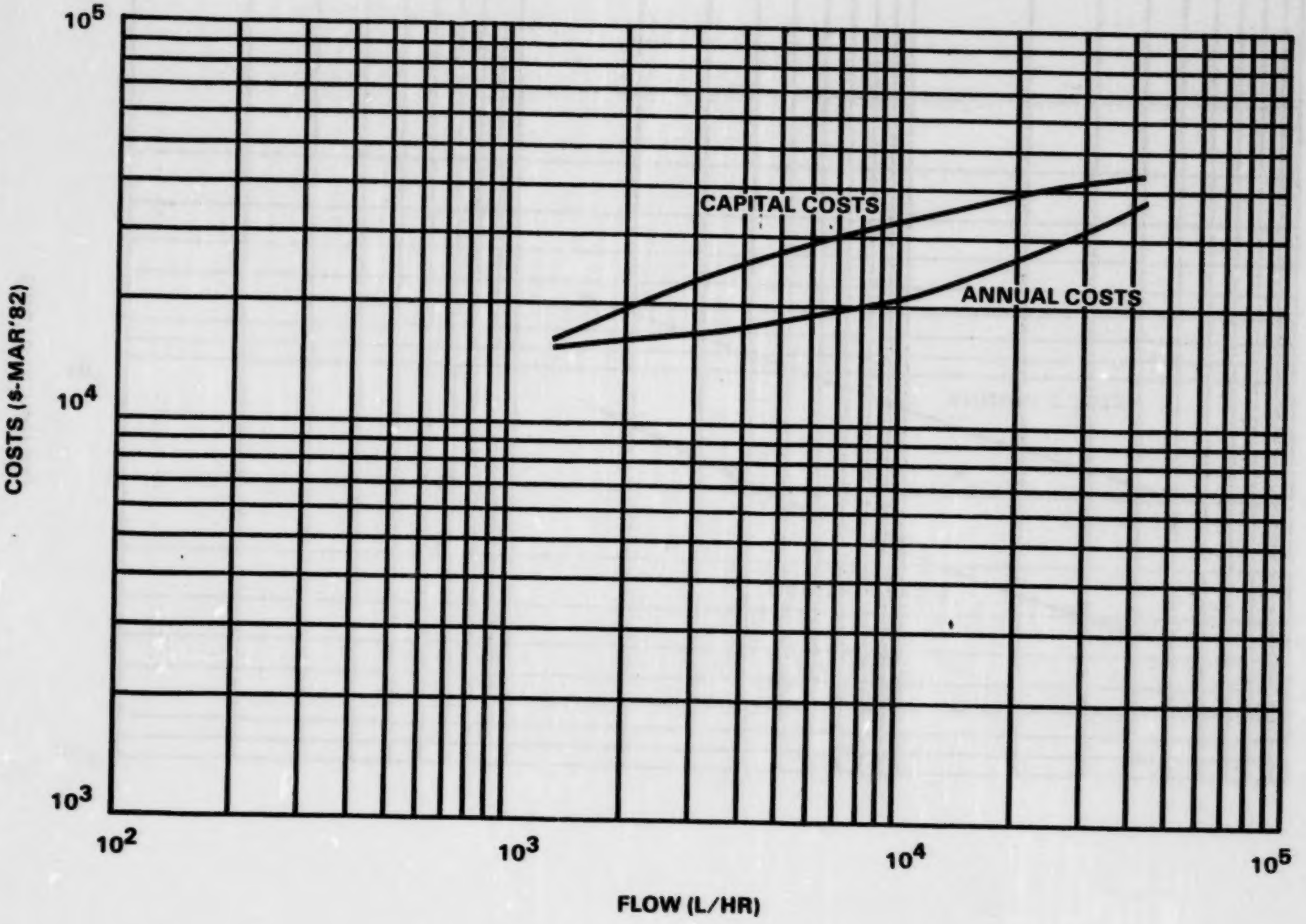


FIGURE VIII-5. COSTS FOR CHROMIUM REDUCTION

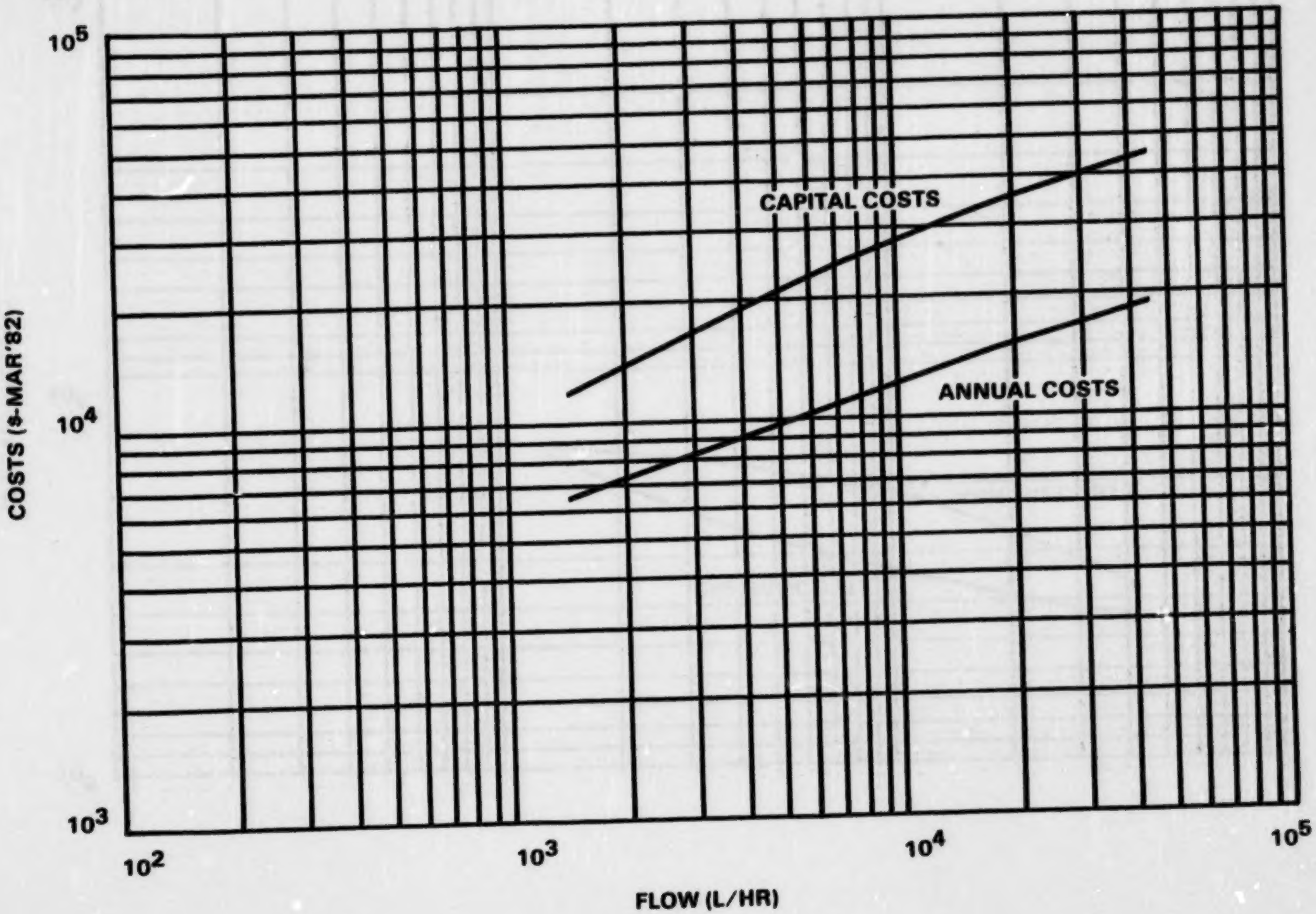


FIGURE VIII-6. COSTS FOR EQUALIZATION

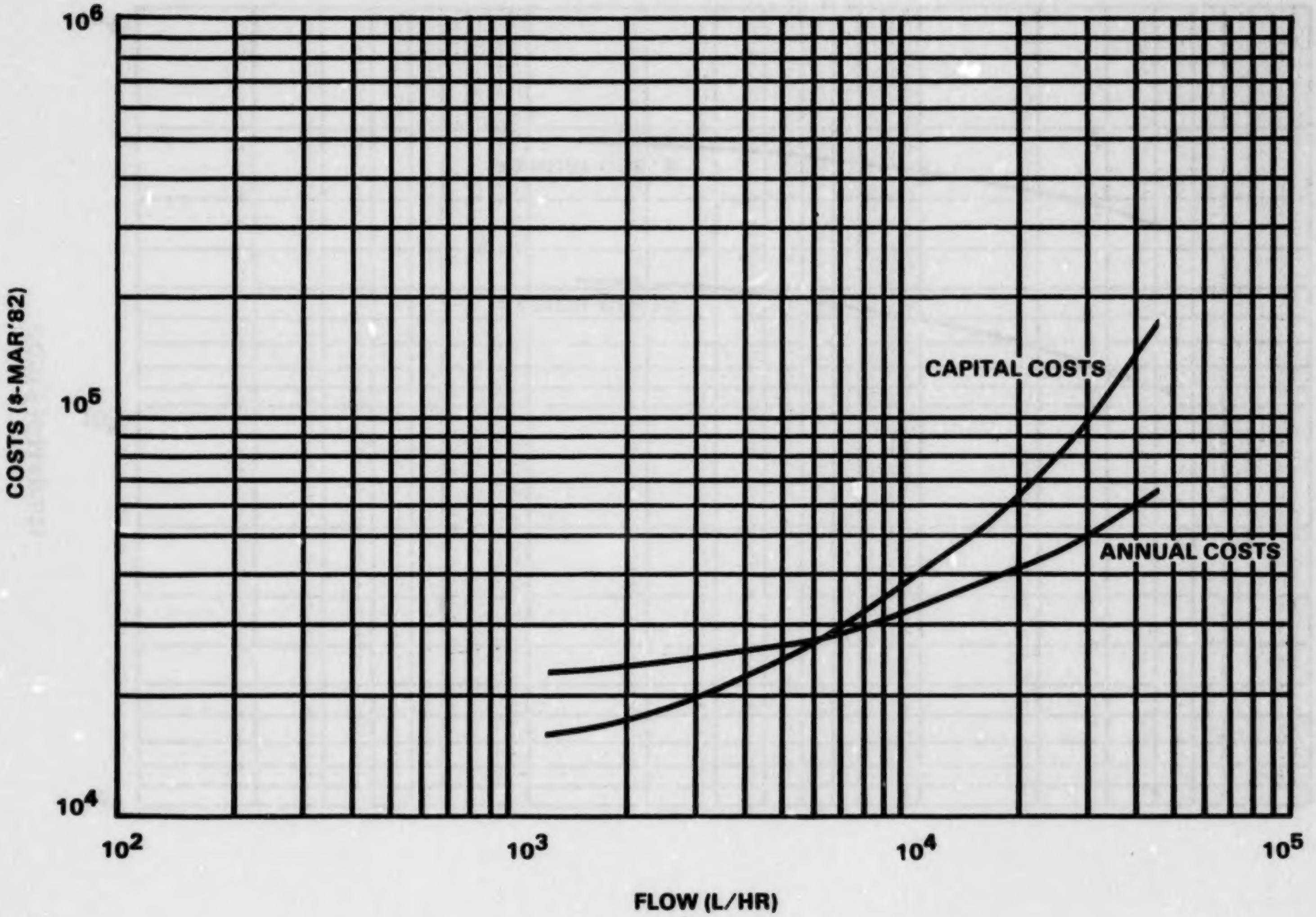


FIGURE VIII-7. COSTS FOR CHEMICAL EMULSION BREAKING

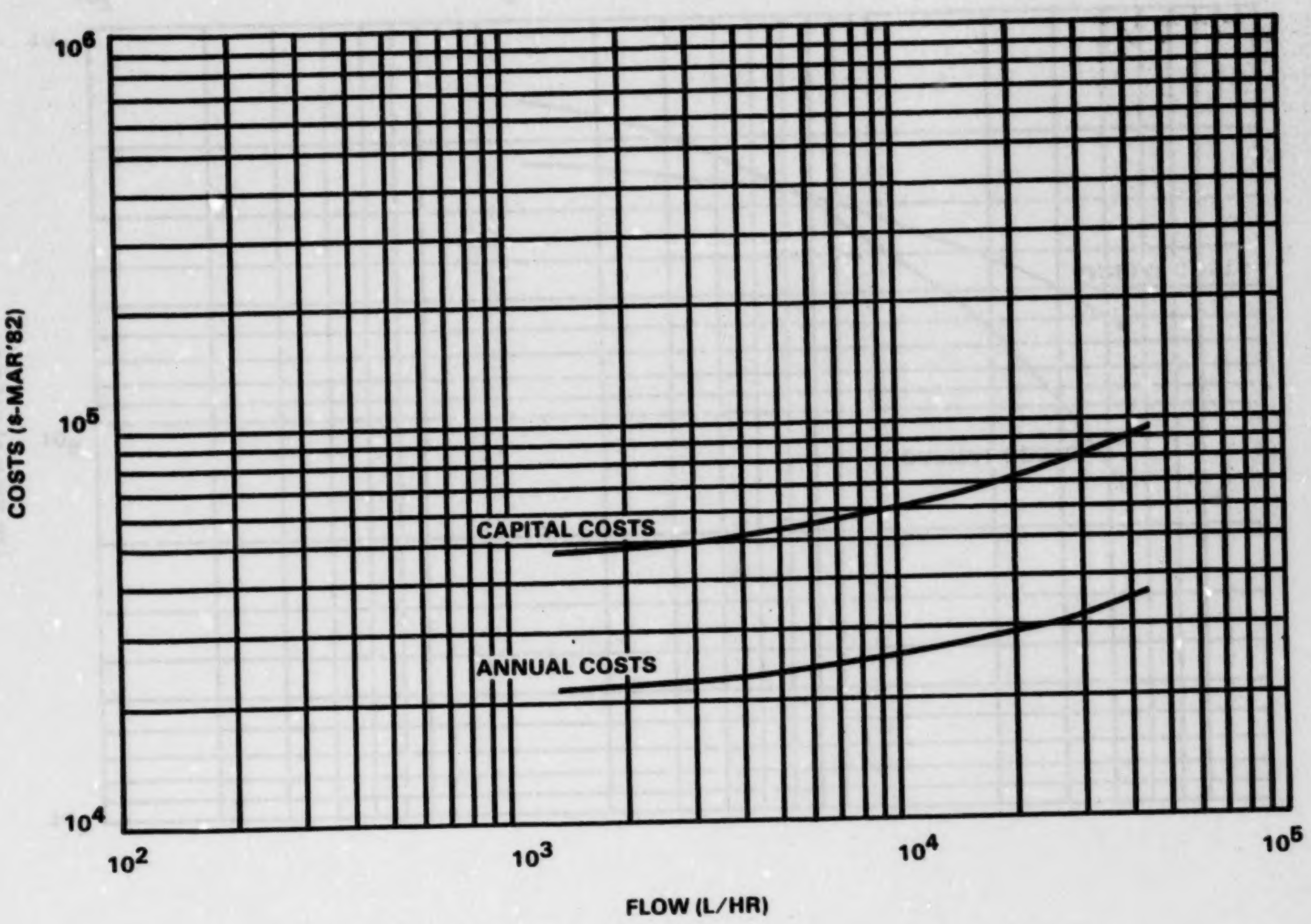


FIGURE VIII-8. COSTS FOR DISSOLVED AIR FLOTATION

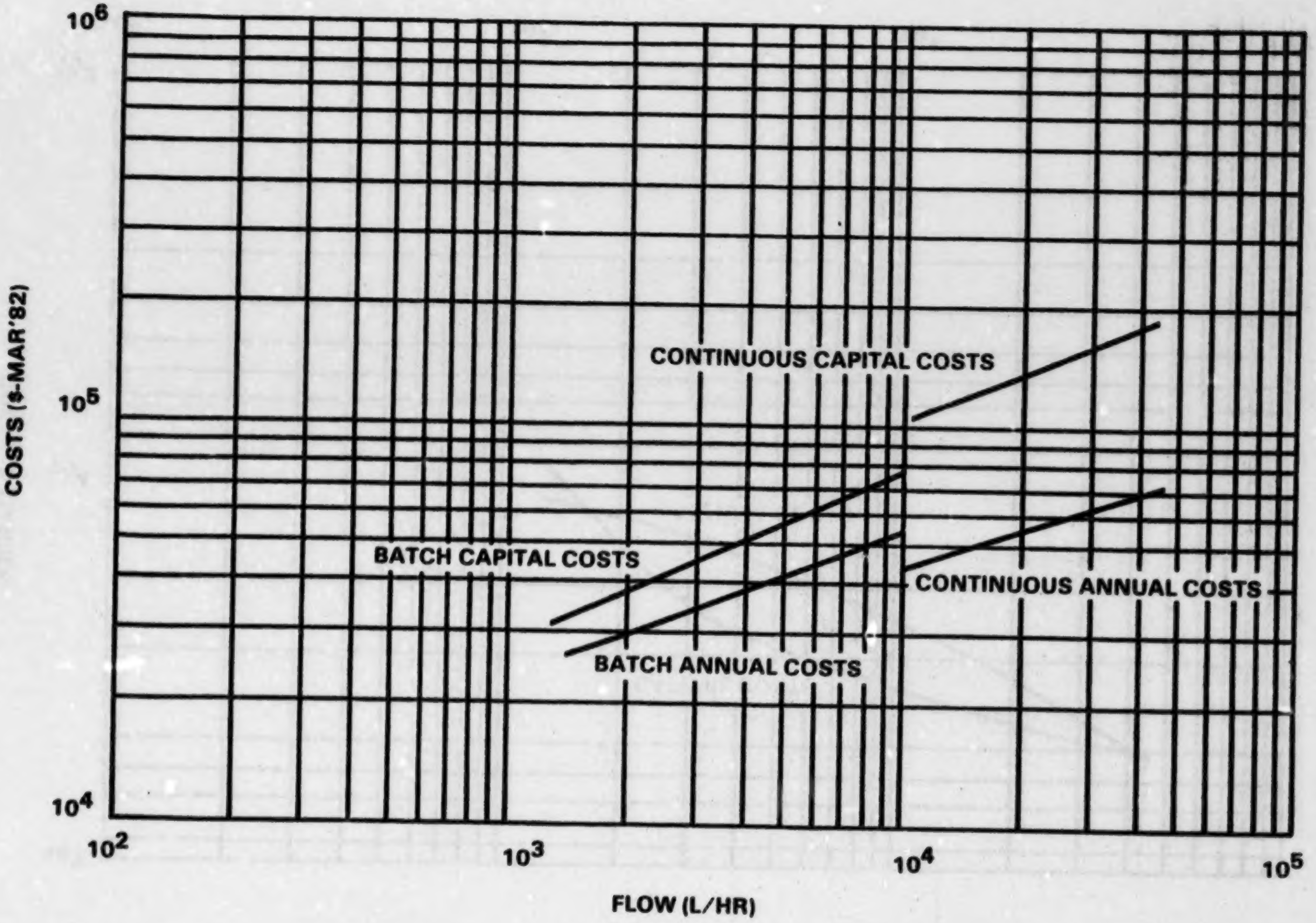


FIGURE VIII-9. COSTS FOR CHEMICAL PRECIPITATION AND SEDIMENTATION

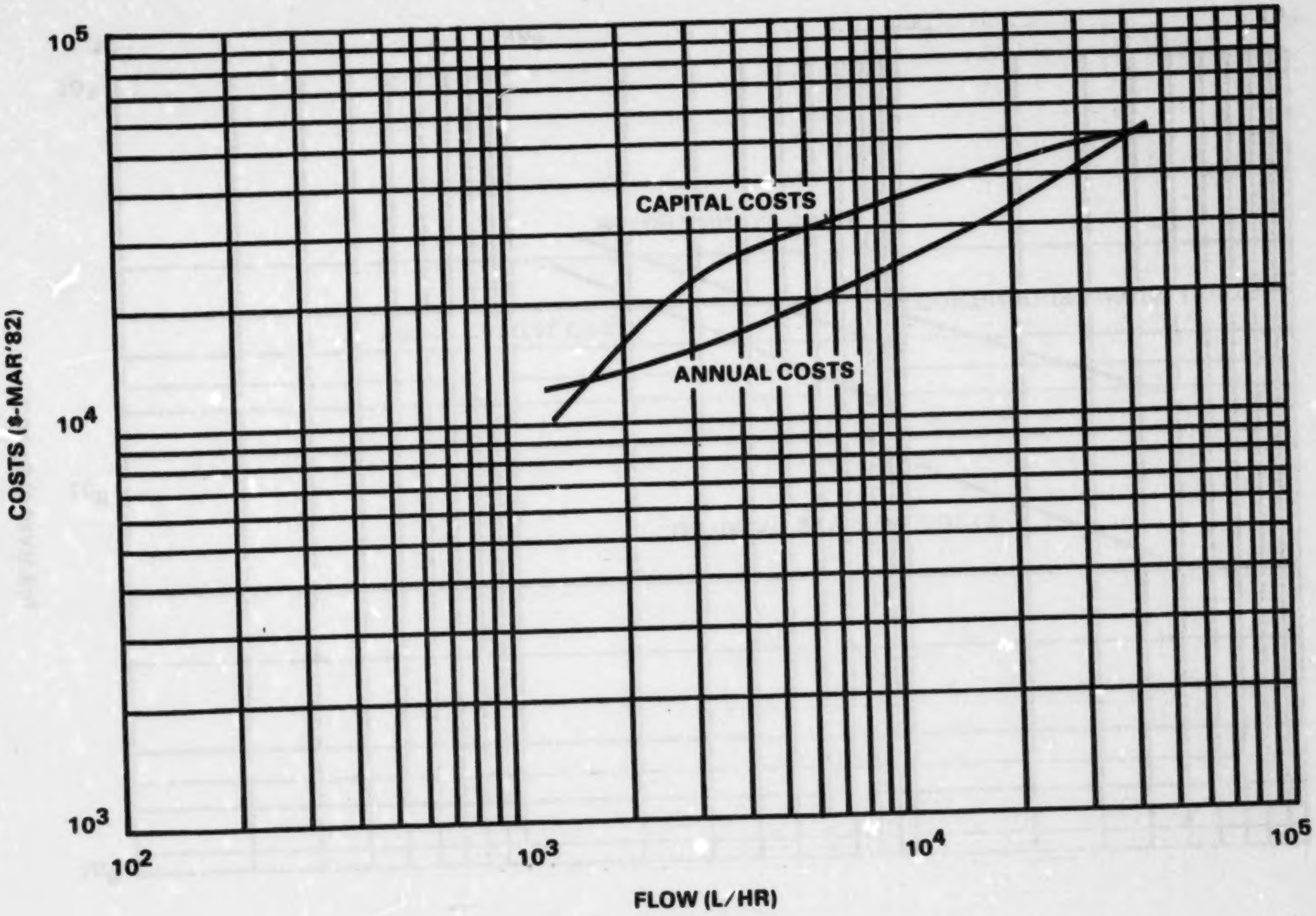


FIGURE VIII-10. COSTS FOR MULTIMEDIA FILTRATION

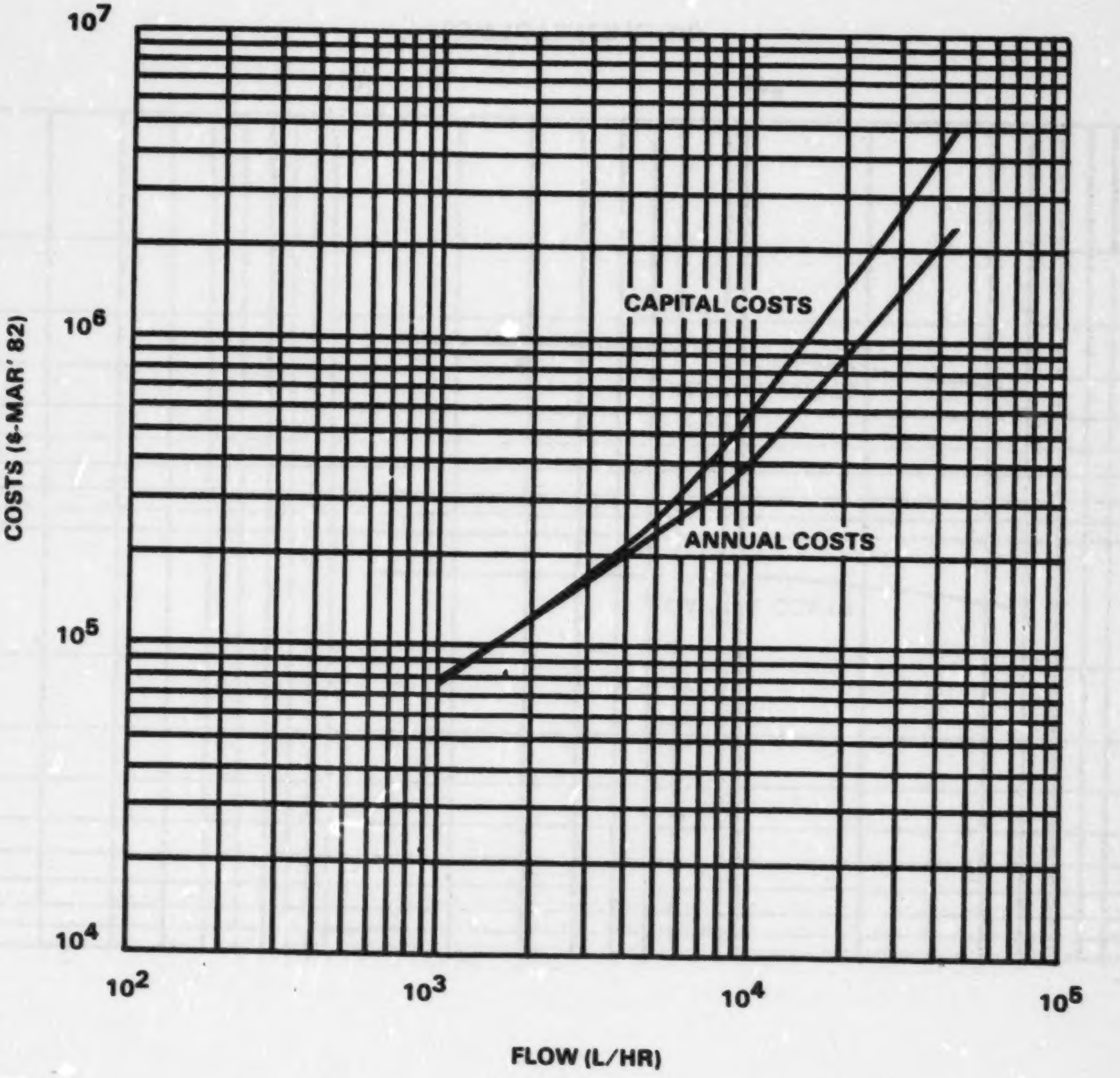


FIGURE VIII-11. COSTS FOR ULTRAFILTRATION

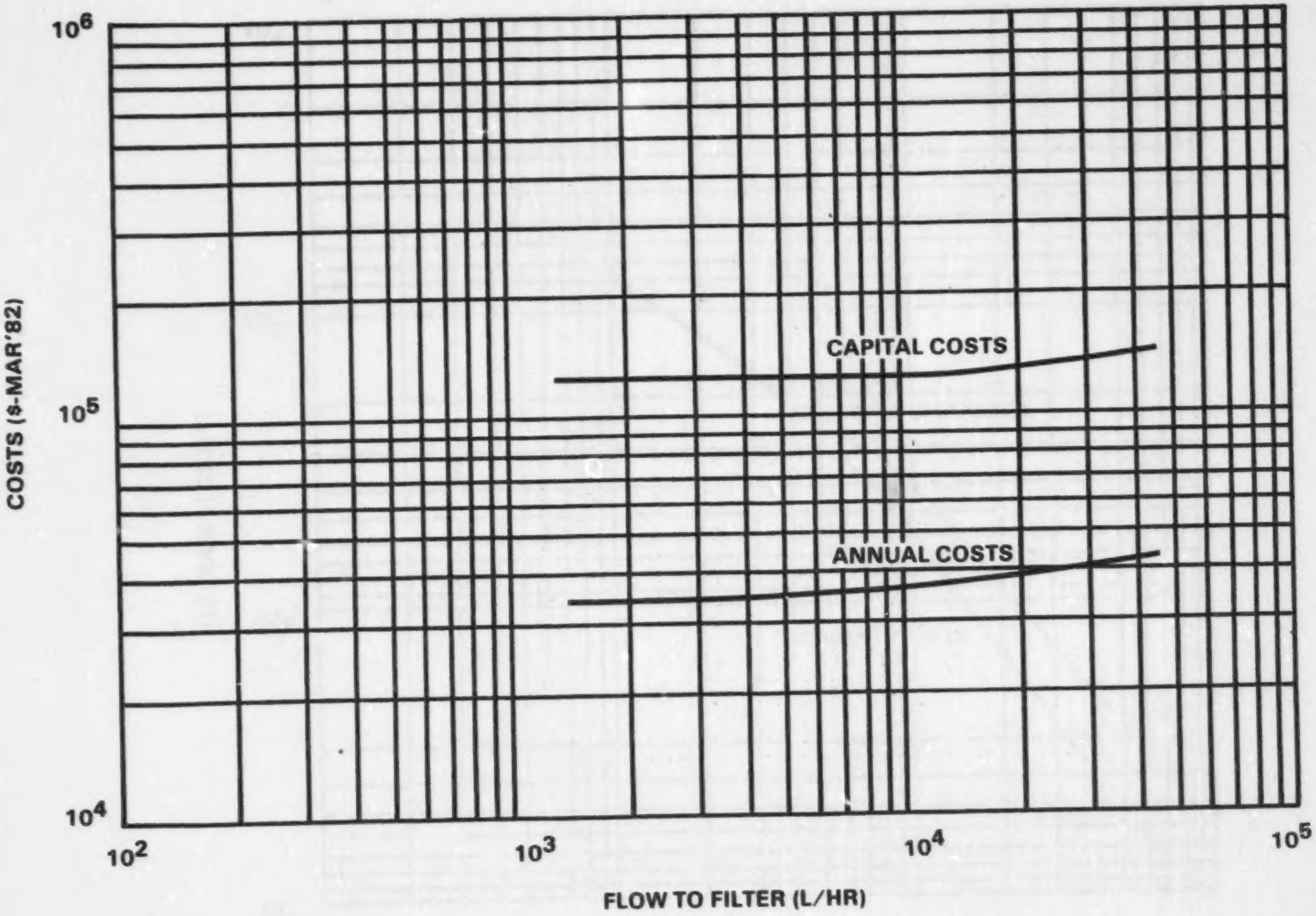


FIGURE VIII-12. COSTS FOR VACUUM FILTRATION

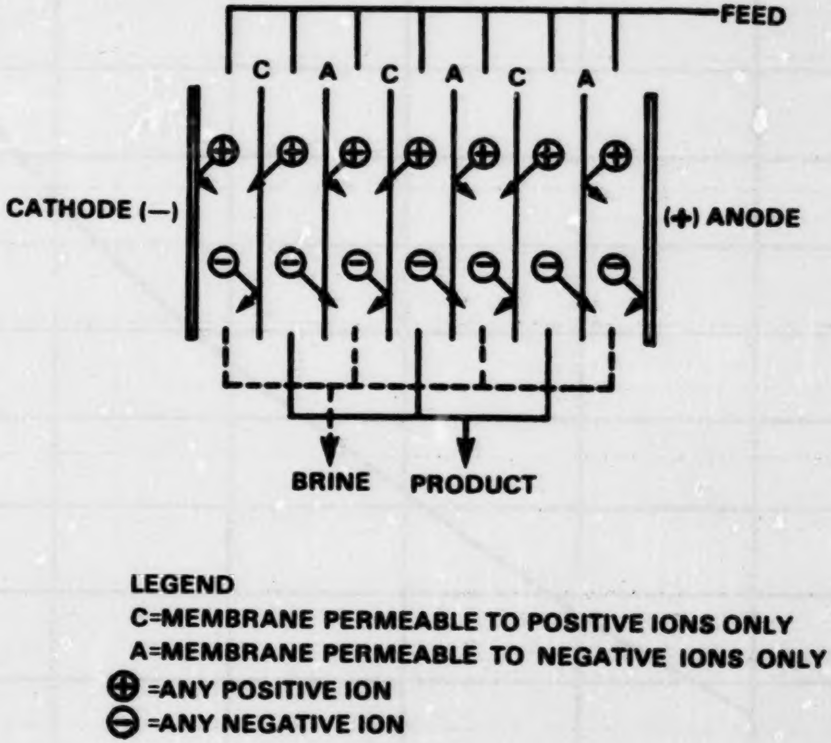

FEED
C
A
C
A
C
A
CATHODE (—)
(+) ANODE
BRINE
PRODUCT
LEGEND
C=MEMBRANE PERMEABLE TO POSITIVE IONS ONLY
A=MEMBRANE PERMEABLE TO NEGATIVE IONS ONLY
⊕ =ANY POSITIVE ION
⊖ =ANY NEGATIVE ION

FIGURE VIII-13. DIAGRAM OF AN ELECTRODIALYSIS UNIT

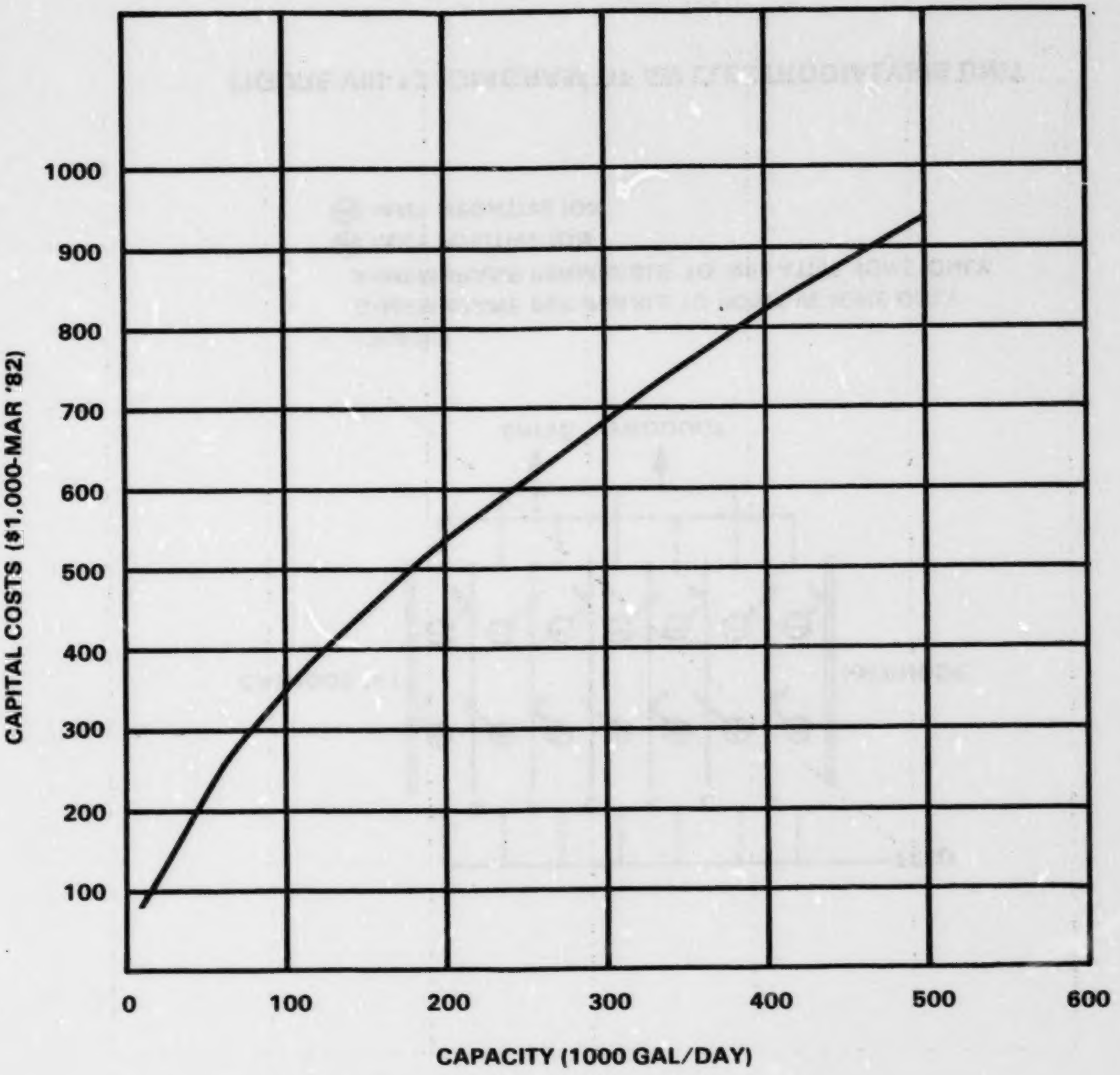


FIGURE VIII-14. CAPITAL COSTS OF ELECTRODIALYSIS

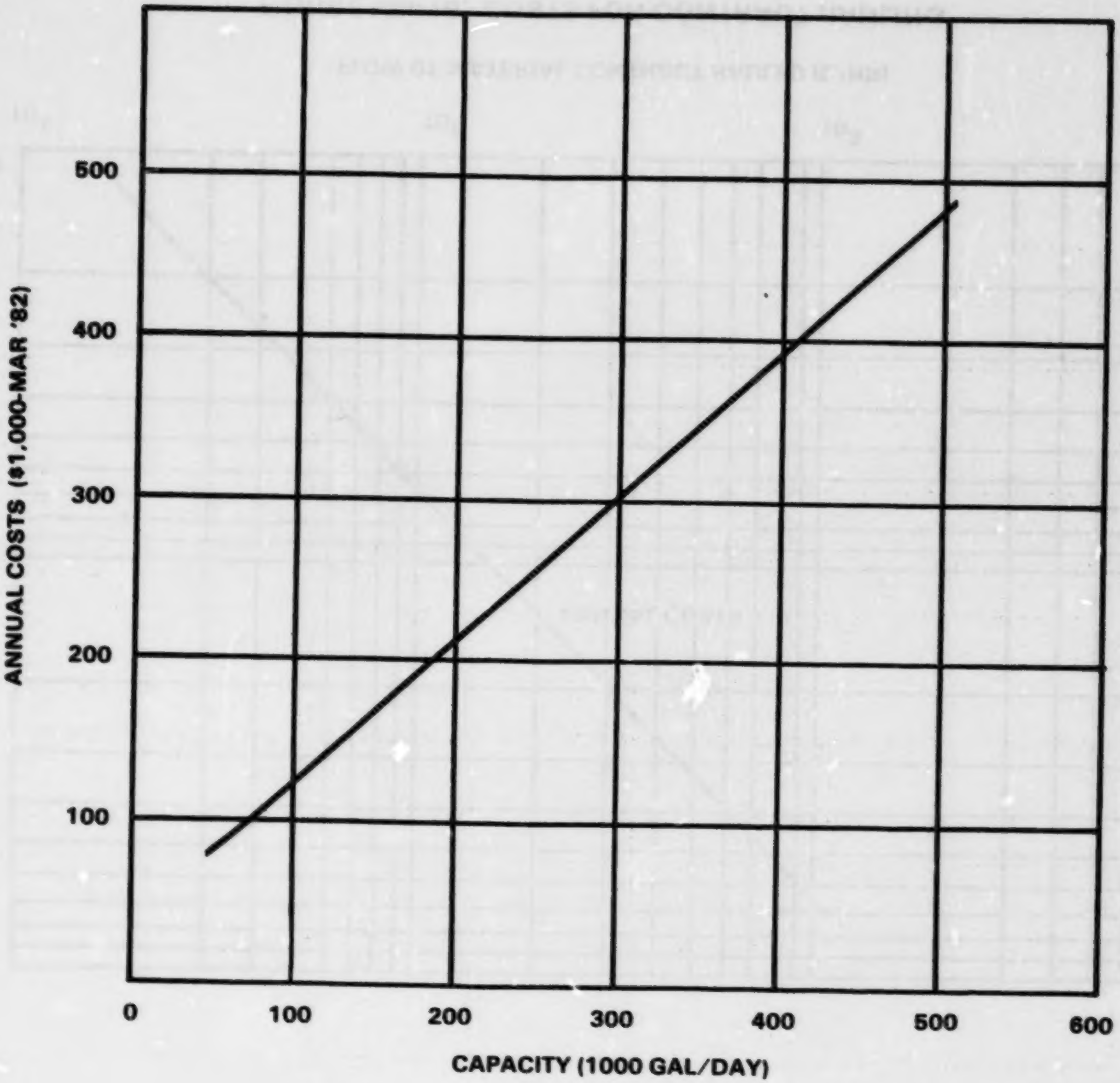


FIGURE VIII-15. ANNUAL COSTS OF ELECTODIALYSIS

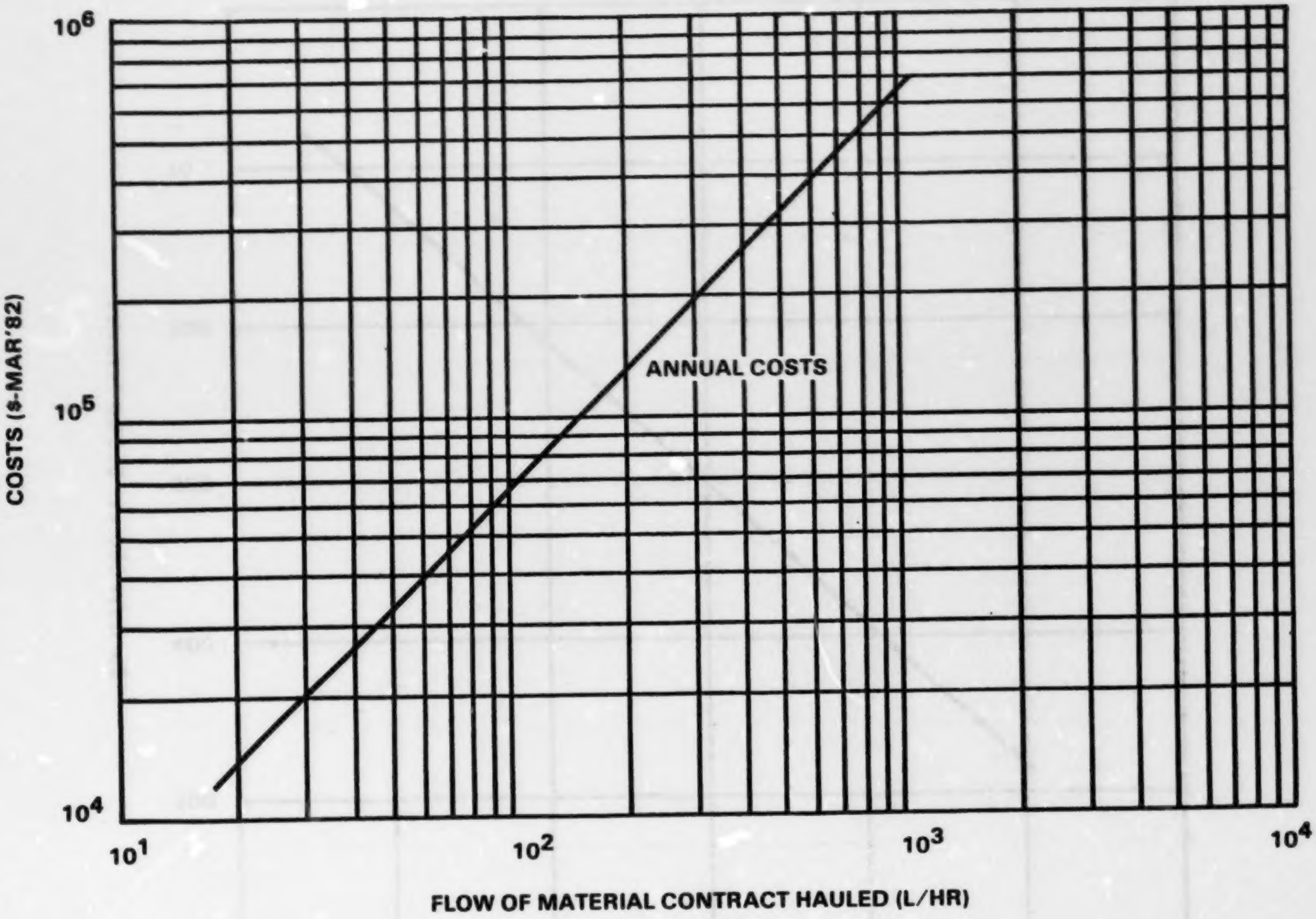


FIGURE VIII-16. COSTS FOR CONTRACT HAULING

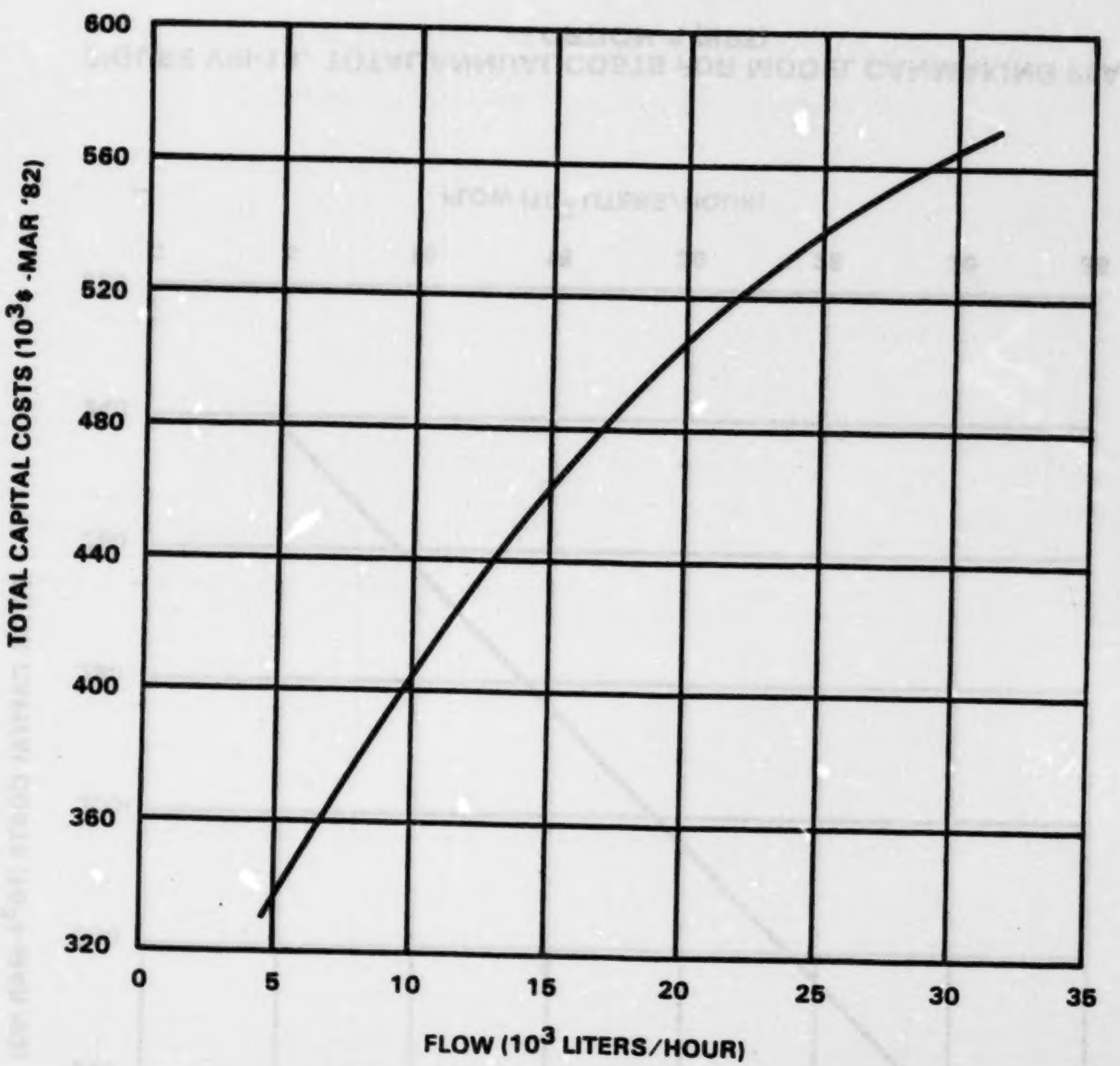


FIGURE VIII-17. TOTAL CAPITAL COSTS FOR MODEL CANMAKING PLANTS — OPTION A (BPT)

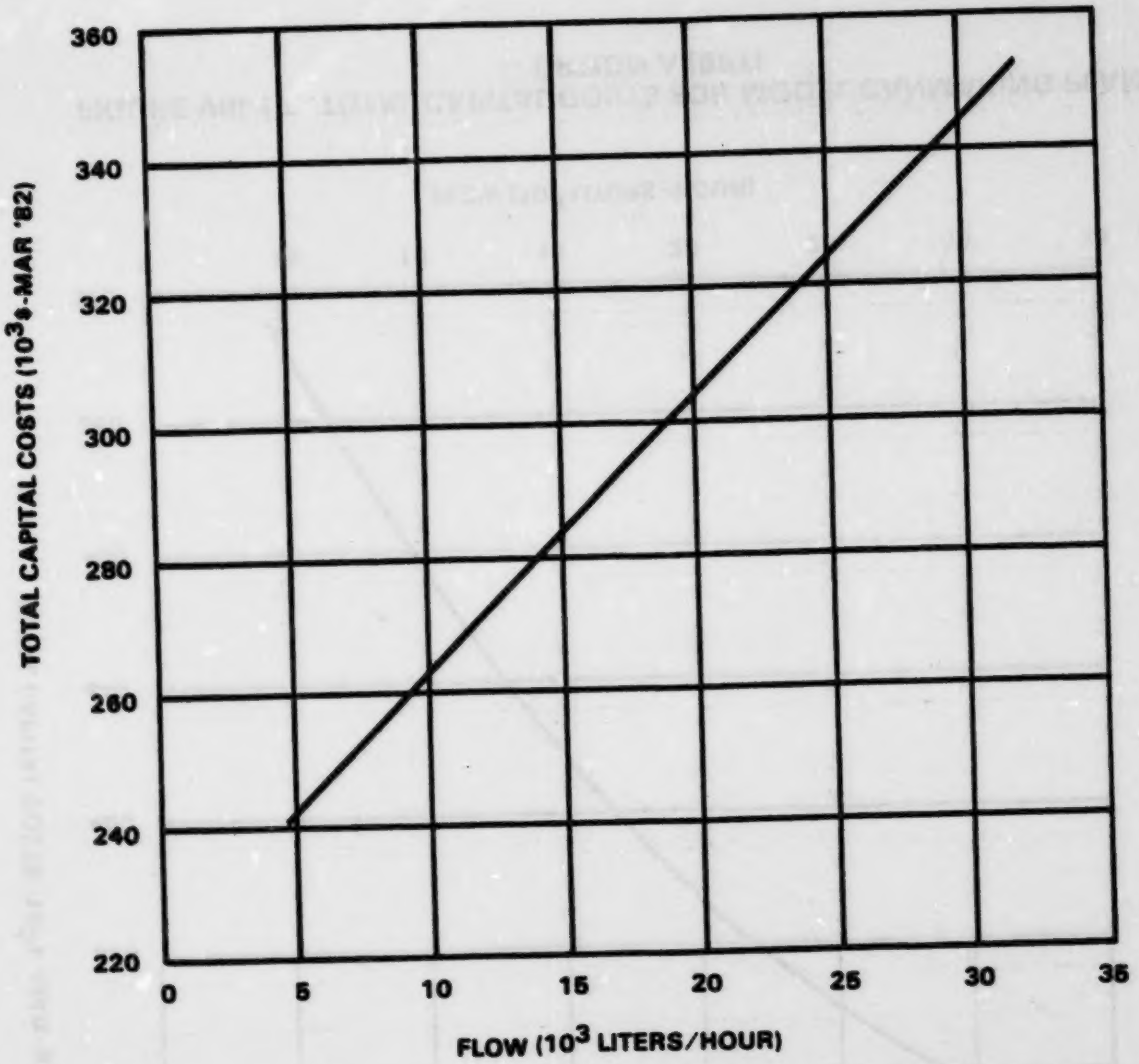


FIGURE VIII-18. TOTAL ANNUAL COSTS FOR MODEL CANMAKING PLANTS — OPTION A (BPT)

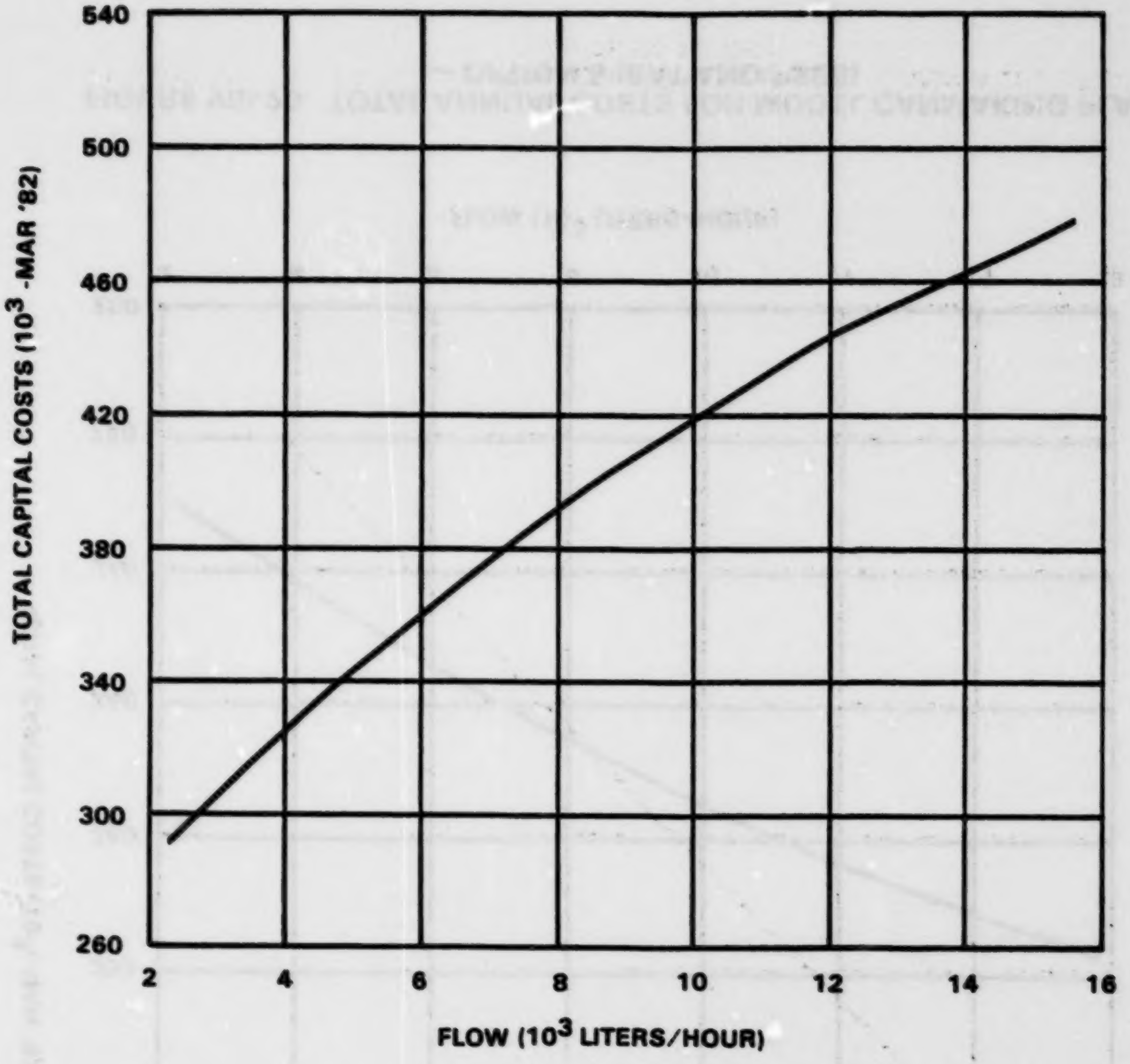


FIGURE VIII-19. TOTAL CAPITAL COSTS FOR MODEL CANMAKING PLANTS — OPTION B (BAT AND PSES)

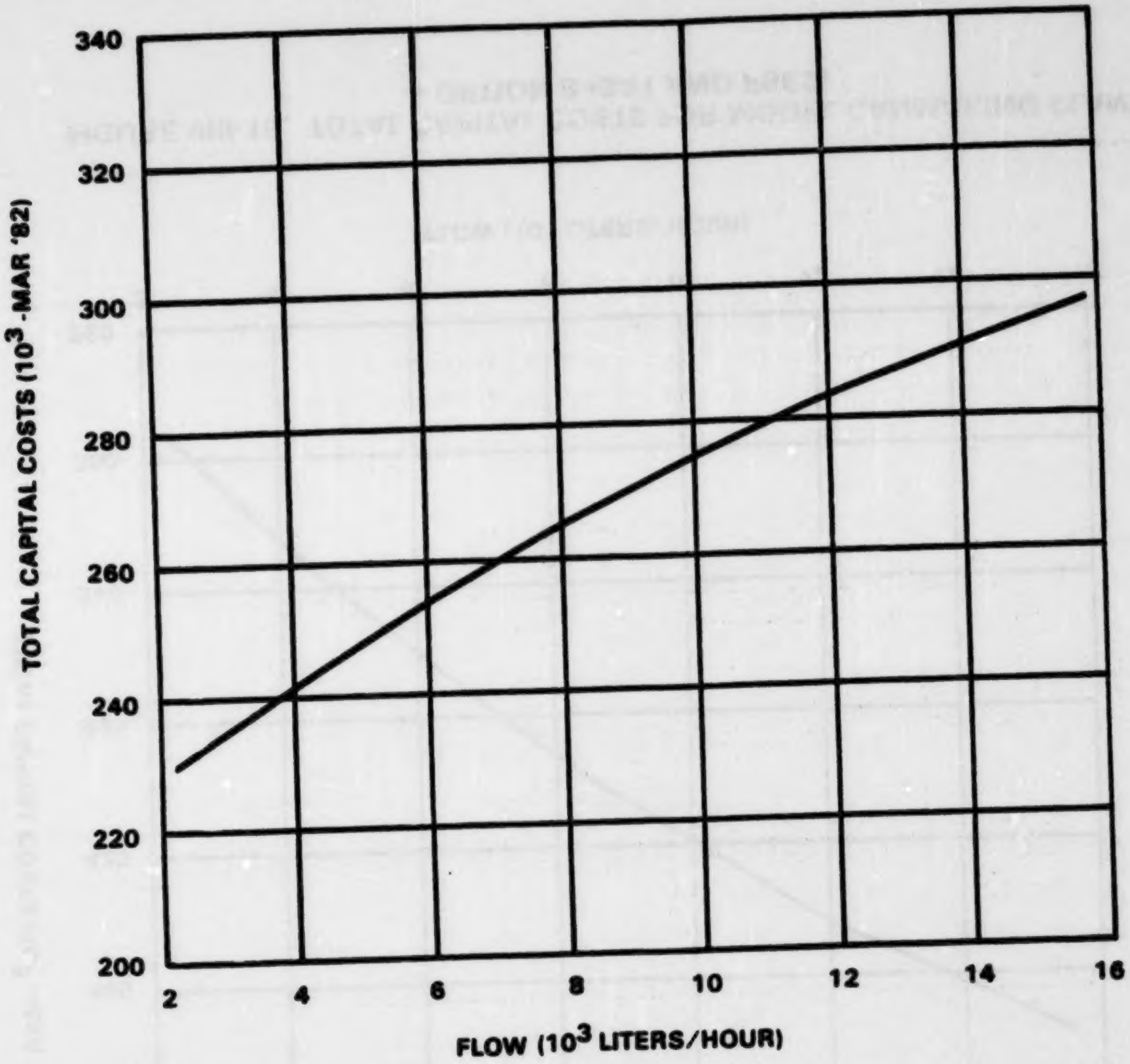


FIGURE VIII-20. TOTAL ANNUAL COSTS FOR MODEL CANMAKING PLANTS — OPTION B (BAT AND PSES)

SECTION IX
BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE

This section defines the effluent characteristics attainable through the application of best practicable control technology currently available (BPT). BPT reflects the performance by plants of various sizes, ages, and manufacturing processes within the canmaking subcategory.

The factors considered in defining BPT include the total cost of applying the technology in relation to the effluent reduction benefits from such application, the age of equipment and facilities involved, the process employed, nonwater quality environmental impacts (including energy requirements) and other factors the Administrator considers appropriate. In general, the BPT level represents the average of the best existing performances of plants of various ages, sizes, processes or other common characteristics. Where existing performance is inadequate, BPT may be transferred from a different subcategory or category. Limitations based on transfer technology must be supported by a conclusion that the technology is, indeed, transferable and a reasonable prediction that it will be capable of achieving the prescribed effluent limits. See Tanners' Council of America v. Train. BPT focuses on end-of-pipe treatment rather than process changes or internal controls, except where such are common industry practice.

TECHNICAL APPROACH TO BPT

EPA first studied canmaking operations to identify the processes used and the wastewaters generated during the canmaking process. The information collected by EPA during the development of this regulation is described in detail in Sections III and V. This information includes complete and updated data collection portfolios (dcp), data from engineering visits to seven plants prior to proposal, data from engineering visits to seventeen plants following proposal, and plant sampling and analysis data. In addition, industry provided information following proposal, including sampling and analysis data at fourteen canmaking plants. The Agency evaluated these data to determine what constituted an appropriate BPT.

Canmaking consists of cupping, drawing and ironing, and washing, where the cans are cleaned and prepared for the decoration process. These process steps generate different wastewater streams. In all wastestreams, as discussed in Sections III and

IV, the volume of wastewater is related to the number of cans processed. As discussed in detail in Section IV, canmaking is regulated as a single subcategory. In this regulation, only seamless cans made from uncoated stock are regulated, since no process water is generated from the manufacture of seamed cans or seamless cans made from coated stock.

BPT limitations are generally based on the average of the best existing performance by plants of various ages, sizes, and unit processes within the subcategory for control of familiar (i.e. classical) pollutants. This document has already discussed some of the factors which must be considered in establishing effluent limitations based on BPT. The age of equipment and facilities and the processes employed were taken into account and are discussed fully in Section IV. Nonwater quality impacts including energy requirements are considered in Section VIII.

The general approach to BPT for this subcategory is to treat all canmaking wastewaters in a single (combined) treatment system. Many plants combine wastewater for treatment because it is less expensive than treating wastestreams separately. Oil, which is used as a lubricant and coolant during the formation of the seamless can body, and is removed during washing, must be removed from the wastewater; and hexavalent chromium, where present, must be reduced to the trivalent state so that it can be precipitated and removed along with other metals. The dissolved metals, phosphorus and fluoride must be precipitated and suspended solids, including the precipitate, removed.

The final model end-of-pipe treatment technology for BPT is oil removal by skimming, dissolved air flotation, or emulsion breaking or a combination of these technologies; chromium reduction when necessary; lime precipitation of other pollutants; and removal of precipitated solids by Stokes' law sedimentation ("lime and settle" technology), (Figure IX-1, page 323). The proposed model end-of-pipe treatment technology also included cyanide precipitation where necessary, but this element was deleted since cyanide was not found in canmaking wastewaters in treatable quantities and was thus not regulated. Nonetheless, cyanide compounds may be used in some conversion coatings so that cyanide precipitation may be necessary in individual cases if these coatings are used.

The strategy for BPT also includes flow normalization through water flow reduction and water reuse practices. These practices are commonly practiced in the subcategory and are described more fully in Sections III and VII. The proposed BPT flow reduction strategy was based on the average production normalized wastewater flow among the 32 plants in the subcategory which EPA believed practiced reuse of process wastewater within the canwasher. This proposed strategy was modified when additional data was received which verified that 14 plants practice reuse using counterflow technology within the canwasher. The final BPT flow is based on the performance of the median plant among the 62 plants in the data base for which we have complete data (Figure IX-2, page 324). Average production normalized data for each plant was displayed in Table V-2 (page 54).

The final BPT limitations are mass-based since concentration-based standards do not limit the quantity of pollutants discharged. The BPT limitations were derived as the product of the BPT flow and the overall effectiveness of the model end-of-pipe treatment technology.

SELECTION OF POLLUTANT PARAMETERS FOR REGULATION

The pollutant parameters selected for BPT limitations in the canmaking subcategory were frequently found at treatable concentrations in wastewaters from some plants. Chromium, zinc, aluminum, fluoride, oil and grease and TSS were frequently found at treatable concentrations in the raw wastewaters of canmaking plants. Chromium appears in wastewaters in treatable concentrations as a result of its continued use in chromating surface treatment in a few instances in the subcategory and as an apparent result of dissolution of chrome-containing steel alloys in canwashers by acid baths. Zinc appears in wastewaters as a consequence of its use as an alloying agent in the aluminum strip used for forming cans, and aluminum appears since it is the principal raw material used. Fluoride is a constituent of hydrofluoric acid, a common process chemical used in canmaking. In addition, phosphorus was found in treatable concentrations in the wastewaters of several canmaking plants, as a result of its use in zirconium phosphate conversion coatings. Oil and grease appears in wastewaters as a result of lubricants used in canmaking cupping and ironing machines. See Section V for details.

The pollutant parameters selected for BPT regulation are chromium, zinc, aluminum, fluoride, phosphorus, oil and grease, TSS and pH. These parameters are the same as proposed. pH is regulated to assure the proper operation of the model end-of-pipe treatment technology for solids removal (lime and settle) and to assure optimum removal of all regulated pollutants except oil and grease. Cyanide is not regulated since it was not found in treatable concentrations in sampled canmaking wastewaters.

CANMAKING SUBCATEGORY BPT

BPT Flow Calculation

The BPT limitations include reductions in flow since the best performing plants in the subcategory achieve significant flow reductions, as presented in Table V-7 (page 59). Most aluminum canmaking plants provided sufficient information in their dcp to calculate the production normalized process water use at plants in the subcategory, which was used to establish BPT regulatory flows.

The flow basis for BPT is the performance of the median plant among the 62 plants in the subcategory for which we had complete data. The median plant was defined as the plant in an even numbered population of plants that will include one-half of the population. The median plant was chosen in preference to the average because the industry provides a skewed distribution of flow values, as illustrated in Figure IX-2; five percent of the 62 plants for which we have complete data account for 16 percent of the total flow. The production normalized water use for the canmaking subcategory at BPT is 215.0 l/1000 cans.

Plants with production normalized flows significantly above the flow used in calculating the BPT limitations will need to reduce flows to meet the BPT limitations. Generally this reduction can be made by using a number of commonly used techniques. These techniques are related to the optimal operation of canwashers, including reduction in the flow to the canwasher (water conservation); maintaining adequate recirculation within each stage of the canwasher until equilibrium is achieved; turning off the water supply to the canwasher when production is stopped; cleaning or replacing plugged spray nozzles; and proper operation and maintenance of the canwasher. These techniques, which are described in more detail in Sections III and VII, are commonly used and can be implemented at all canmaking plants in the subcategory to achieve the BPT flow.

Prior to establishing the BPT flow, the Agency evaluated thirteen specific factors which commenters identified following proposal as possible barriers to the achievement of flow reductions. These factors are:

- Customer requirements for end use
- Quality of incoming fresh water
- Can bottom geometry with respect to drag-in and drag-out
- Can geometry (height/diameter ratio)
- Washer age and design
- Customer can quality requirements
- Type of organic coating to be applied
- Type of lubricants to be washed off
- Surface finish on can forming tooling
- Type of label used

- o Insensitivity of water use to variations in number of cans washed
- o Size of canwasher
- o Location of plant in arid or wet regions of the country.

These factors were evaluated using data provided by commenters, data contained in the data collection portfolios for the industry, and data received on plant visits and in response to Agency requests for further information after proposal. EPA concluded that none of these thirteen factors will prevent the achievement of the estimated flow reductions for this regulation by any plant.

One factor examined is whether the taste of beer and other malt beverages is more sensitive to contaminants than is the taste of soft drinks, and that additional rinse water is therefore required for beer cans than for soft drink cans. An additional question examined is whether more water is necessary for light beers than for heavier pilsners, lagers, or ales for the same reason. The Agency examined canmaking plants of four companies which produce cans for both soft drinks and beer, and additional plants which produce cans for both light beer and other malt beverages. EPA found that on the basis of information supplied by the industry, wastewater flows in each plant do not vary with the intended use of the can. Further, a number of the lowest wastewater flow rates in the industry are found at plants which manufacture cans primarily intended for beer. As a result, we concluded that reduced flows are achievable regardless of whether cans are manufactured for beer or for soft drinks.

Another factor examined is whether the quality of fresh makeup water, which varies from location to location, restrains the achievable flow reduction. The industry identified about three plants as experiencing product quality problems related to the quality of the fresh water supply. The Agency visited several of those plants and talked with company officials, and we do not believe that the specific product quality problems these plants are experiencing are due to an excess of dissolved solids in the fresh water supplied to the canwashers. In general, EPA concludes that while site-specific water quality factors could conceivably require additional water purification steps or the addition of water treatment chemicals in a few instances, data submitted by commenters and other data available in the record do not support a contention that quality of makeup water limits the degree of flow reduction achievable. The cost of such pretreatment steps was examined and is included in Section VIII.

Another factor mentioned in comments is that routine production stoppages restrict a company's ability to meet reduced water flow allowances, since water flow allowances are expressed as a function of production. The Agency found no support for this contention, since can plants can reduce or turn off the supply of water to the washer during production stoppages.

Canwasher age and design, canwasher mat width, and can geometry were also examined as factors which could affect a company's ability to achieve the reduced water flow. EPA found only one of these factors, age and design, to have any demonstrable relation to water use. Water use at canmaking plants tends to vary with age and design, but we visited several units of varying ages and designs and found no engineering reason why improved recycle, reuse, and water conservation practices cannot be implemented at these canwashers to achieve the reduced flows of this reguation.

Commenters also asserted that the type of organic coating to be applied, the type of lubricant to be washed off, the surface finish on can tooling, and the type of label used all affect achievable reductions in flow rates. Despite requests for industry to provide data to substantiate these claims, only general statements were provided for the record. In plant visits and in subsequent information requests sent by EPA under the authority of section 308 of the Act, attempts were made to determine the possible effects of these factors, but no specific data were obtained. The remaining factors identified by commenters were similarly examined with similar results. The Agency thus concludes that based on the record, these factors do not appear to prevent any plant from achieving the flows used for calculating the limitations and standards in this regulation.

In summary, the Agency has conducted numerous engineering plant visits and exhaustively examined the information available in the record, and finds no supportable reason why the BPT flow cannot be achieved in every canmaking plant. Since flow reductions for BPT are demonstrated at at least 31 plants, the Agency concludes that the BPT flow can be achieved by all plants in the subcategory.

BPT Treatment Effectiveness

The BPT model end-of-pipe treatment train for canmaking wastewater consists of oil removal by skimming, dissolved air flotation, chemical emulsion breaking, or a combination of these technologies; chromium reduction when necessary; mixing and pH adjustment of the combined wastewaters with lime to precipitate metals; followed by Stokes' law sedimentation ("lime and settle"). This technology was selected as the model end-of-pipe treatment technology since it is the most effective technology for removing the pollutants of concern. Many plants in the subcategory presently rely on dissolved air flotation (DAF) as the primary device for removing solids. The Agency noted this, but determined that DAF is not as effective as lime and settle for the removal of solids, based in part upon sampling data submitted by the industry. See Tables V-13 (page 68) and V-17 (page 80) and the discussions in Section VII for further details.

Lime and settle technology is the model end-of-pipe treatment technology for the removal of precipitated metals, fluoride, phosphorus, and other solids. Lime (rather than caustic) is necessary as a source of calcium in order to precipitate calcium fluoride, which is the insoluble fluoride species. Eleven of the 62 plants for which we have complete data indicate that they employ lime and settle technology. Further, four plants indicated that they employ chromium reduction equipment, which may be necessary in some cases to reduce hexavalent chromium to trivalent chromium prior to precipitation and removal. Five canmaking plants appear to have all elements of the model BPT end-of-pipe treatment technology described above already in place.

Available sampling and analysis data from treated effluents in the canmaking subcategory is inadequate to establish the treatment effectiveness of lime and settle technology. As described in Section V, the Can Manufacturers Institute (CMI) and the United States Brewers Association (USBA) submitted sampling and analysis data for fourteen plants. This data is presented in Table V-16. Only three of these plants, Plants 530, 565, and 605, employ and optimally operate lime and settle treatment technology, based on information submitted by companies and as observed during plant visits. Of these, the first data day at Plant 565 was rejected as anomalous, as inconsistent with historical sampling at that plant, and with the remaining two data days for the plant submitted by CMI and USBA. Thus, the Agency determined that a total of eight days of sampling data submitted by CMI and USBA was representative of optimally operated end-of-pipe treatment technology for removal of metals, fluoride, phosphorus, and TSS.

For TSS, chromium, and zinc, the Agency determined that the Combined Metals Data Base (CMDB) was the best available and most appropriate basis for establishing the treatment effectiveness of the model end-of-pipe treatment technology on wastewaters from the canmaking subcategory. As described in Section VII, the CMDB consists of 162 data points from 18 plants, (including one plant in the canmaking subcategory), thus providing a larger data base and better sampling reliability in comparison to the few other data points available from the canmaking subcategory. Further, this larger data base enhances the Agency's ability to estimate long-term performance and variability through statistical analysis.

To determine whether this transfer of treatment effectiveness data is appropriate, statistical tests of homogeneity were applied prior to proposal to raw wastewaters from the canmaking plants and the wastewaters of categories represented in the combined metals data base. As described in Section VII, these tests revealed the canmaking raw wastewaters to be homogeneous with the wastewaters of the categories represented in the combined metals data base. Following proposal, the Agency performed additional statistical analyses of untreated and treated wastewaters, using EPA sampling data and data supplied by CMI and USBA. These analyses confirmed the general homogeneity of canmaking wastewaters with the wastewaters of the CMDB categories, although this analysis showed the concentrations of zinc in canmaking influent wastewaters are significantly lower than those represented in the CMDB. Therefore, in the absence of adequate data from optimally operating BPT end-of-pipe treatment operating technology where it is installed at canmaking plants, EPA considers transfer of treatment effectiveness data from the combined metals data base to be appropriate.

This transfer of treatment effectiveness data is confirmed by the eight data days of sampling submitted by CMI and USBA which represent optimally operated lime and settle treatment systems. All eight of these data points meet the achievable concentrations for TSS, chromium and zinc indicated by the CMDB and used in the final regulation.

Due to the lack of adequate treatment effectiveness data for aluminum in the canmaking subcategory, the achievable concentration value for aluminum is based upon data from the aluminum forming and coil coating categories. This value, 6.43 mg/l as a daily maximum, is slightly increased from proposal to reflect additional information received from the performance of lime and settle treatment systems at aluminum forming plants. To determine whether the transfer of this treatment effectiveness data to the canmaking subcategory is appropriate, the Agency compared the aluminum concentrations measured in raw and treated wastewaters of the plants used to establish the treatment effectiveness of aluminum with the concentrations of aluminum in the wastewaters of canmaking plants. The comparison showed no significant difference in the aluminum concentrations from the two groups.

The aluminum concentration used in this regulation is confirmed by Discharge Monitoring Report data (DMR) for one direct discharger in the canmaking subcategory which employs and optimally operates a lime and settle treatment system. These DMR data show that this plant met the aluminum concentration used in this regulation for all but two months in the past two years. In addition, the Agency determined that this aluminum concentration value was met on six out of the eight sampling days submitted by CMI and USBA which represent optimally operated lime and settle technology.

Close pH control is necessary for the proper operation of lime and settle in order to assure optimum removal of metals, as described in detail in Section V and shown in Table VII-1. When pH falls below 7.0, metals, fluoride, and phosphorus are not removed. When pH rises above 10.0, metals that become soluble as oxygenated species return to solution. The lower end of the pH range in the final canmaking regulation has been lowered from 7.5 at proposal to 7.0, to allow greater flexibility for the optimal removal of aluminum from canmaking wastewaters. Data from the optimally operated lime and settle systems in the aluminum forming category show optimal aluminum removal in the range of pH 7.5 to 7.8. The lower end of the pH range in the final aluminum forming regulation was lowered to 7.0 in order to provide treatment plant operators with a reasonable operating range around the optimal pH level necessary to achieve removal of aluminum. The same approach has been adopted in the final canmaking regulation.

The achievable concentration values for phosphorus and fluoride were based at proposal upon data from electroplating and the CMDB (for phosphorus) and the electrical and electronic components industry (for fluoride). These values were not changed from proposal. The concentrations of fluoride and phosphorus in canmaking wastewaters are comparable to the concentrations of these pollutants in the wastewaters of the categories from which the treatment effectiveness concentrations were derived (see Section VII). Further, we found that the CMI and USBA data for the eight sampling days described above met the proposed values for phosphorus and fluoride without exception. As a result, we concluded that the concentrations for these two pollutants used at proposal should be retained in the final regulation.

The discussion above describes the derivation of BPT concentrations which represent the treatment effectiveness of lime and settle technology for removal of metals, fluoride, phosphorus, and TSS. For oil and grease, the model end-of-pipe treatment technology is skimming, chemical emulsion breaking, dissolved air flotation or a combination of these technologies. Forty-one of the 62 plants for which we have complete data indicate that they employ the model oil removal technology, including 20 plants which use dissolved air flotation.

The treatment effectiveness of the model oil removal technology is well demonstrated, as presented in Section VII. The final concentration for oil and grease is presented in Table VII-21, and is the same as proposed. The sampling and analysis data submitted by CMI and USBA include 27 data days which represent optimally operated oil removal technology, as presented in Table V-16. Data for Plants 530, 578, 666, and 667 are not included in this total since these plants either do not employ the model oil removal technology or do not optimally operate the technology, as determined by EPA during engineering visits to the plants. In addition, the first day of sampling at Plant 565 is not included for the reasons described earlier in the discussion of lime and settle technology.

Based upon confidential information obtained by EPA during engineering plant visits, the 13 influent samples provided by CMI and USBA were not representative of the total raw wastewater since they exclude or pretreat oily wastewaters from the raw wastewater prior to the application of the model oil removal technology. As a result, the data submitted by CMI and USBA were useful for confirming the reasonableness of the BPT concentrations but not to establish these concentrations.

All the data supplied by CMI and USBA which represent optimally operated oil removal technology met the oil and grease concentration used in this regulation. In addition, the Agency has considered oil removal in DMR data from copper forming and aluminum forming because these metal forming processes are similar to canmaking processes and require the use of similar lubricants. In particular, the treatment of oil and grease in aluminum forming presents similar problems to canmaking. All of the 170 daily values for oil and grease in aluminum forming DMR data met the one-day limitation concentrations and all of the 46 monthly average values met the monthly average concentration value. This provides a high degree of confidence that canmaking plants can meet the oil and grease limitations.

Typical characteristics of total raw wastewater for the canmaking subcategory are given in Table V-11. The model end-of-pipe treatment technology will reduce the concentration of regulated pollutants to the levels described in the lime and settle column of Table VII-21. When these concentrations are multiplied by the regulatory flow basis described above, the mass of regulated pollutants allowed to be discharged per 1000 cans is readily calculated. Table IX-1 (page 322) shows the limitations derived from this calculation.

EPA reviewed the data for regulated pollutant parameters to determine how many plants are presently meeting the BPT mass limits (see Table V-19, page 84 and Table V-20, page 85). Three sampled plants have all elements of the model treatment system in place and met the BPT flow on a total of 11 of 12 sample days. Plant 565 met all mass limitations for all pollutants on all six sampling days (except for one oil and grease data point), despite low pH readings for three days. Plant 530 met the mass limitations for all pollutant parameters on all three sampling days, while meeting the BPT regulatory flow on all three days. Plant 605 met the mass limitations for all pollutant parameters on all three sampling days, except for one aluminum data point.

Other sampled plants have some elements of the model treatment system in place, but not all components. Including the three plants described above, data from a total of fifteen plants were examined: four plants sampled by EPA prior to proposal and fourteen plants sampled by CMI and USBA after proposal (three plants were sampled by both EPA and CMI and USBA). Each was sampled for three days for the eight regulated pollutant parameters, yielding a total of 399 data points (taking missing data points into account). Mass limitations for chromium were met at 54 of 54 data points; mass limits for zinc were met at 52 of 54 data points; mass limits for fluoride were met at 45 of 47 data points; and mass limits for phosphorus were met at 45 of 45 data points. TSS mass limits were met on 42 of 54 data points and aluminum mass limits were met on 24 of 50 data points. The BPT pH limits were met on 31 of the 49 sampling days for which pH data was reported. Mass-based oil and grease limitations were met on 37 of 46 days. Based on these comparisons, the proposed BPT limitations are reasonable.

Cost and Effluent Reduction Benefits of BPT

In establishing BPT, the cost of applying a technology must be considered in relation to the effluent reduction benefits achieved by such application. The quantity of pollutants removed by BPT is displayed in Table X-4 (page 334) and the total cost of application of BPT is shown in Table X-5 (page 335). The methodologies used in calculating these costs are presented in Sections VIII. The capital cost of BPT as an increment above the cost of in-place treatment equipment is estimated to be $0.743 million. Annual cost of BPT for the canmaking subcategory is estimated to be $0.645 million. The quantity of pollutants removed above raw waste by the BPT system for the subcategory is estimated to be 3.79 million kg/yr including 2,234 kg/yr of toxic pollutants. EPA believes that the effluent reduction benefit outweighs the cost of compliance with BPT.

TABLE IX-1

BPT EFFLUENT LIMITATIONS
CANMAKING SUBCATEGORY

	BPT Effluent Limitations			
Pollutant or Pollutant Property	Maximum for any one day		Maximum for monthly average	
	g (lbs)/1,000,000 cans manufactured			
*Chromium	94.60	(0.209)	38.70	(0.085)
Copper	408.5	(0.901)	215.0	(0.474)
Lead	32.25	(0.071)	27.95	(0.062)
Nickel	412.8	(0.910)	273.05	(0.602)
*Zinc	313.90	(0.592)	131.15	(0.289)
*Aluminum	1382.45	(3.048)	688.00	(1.517)
*Fluoride	12792.50	(28.202)	5675.00	(12.513)
Iron	258.0	(0.569)	131.15	(0.289)
Manganese	146.2	(0.322)	62.35	(0.137)
*Phosphorus	3590.50	(7.916)	1468.45	(3.237)
*Oil and Grease	4300.00	(9.480)	2580.00	(5.688)
*TSS	8815.00	(19.434)	4192.50	(9.243)
TTO	68.8	(0.152)	32.25	(0.071)
*pH	Within the range of 7.0 to 10 at all times.			

*Regulated pollutant

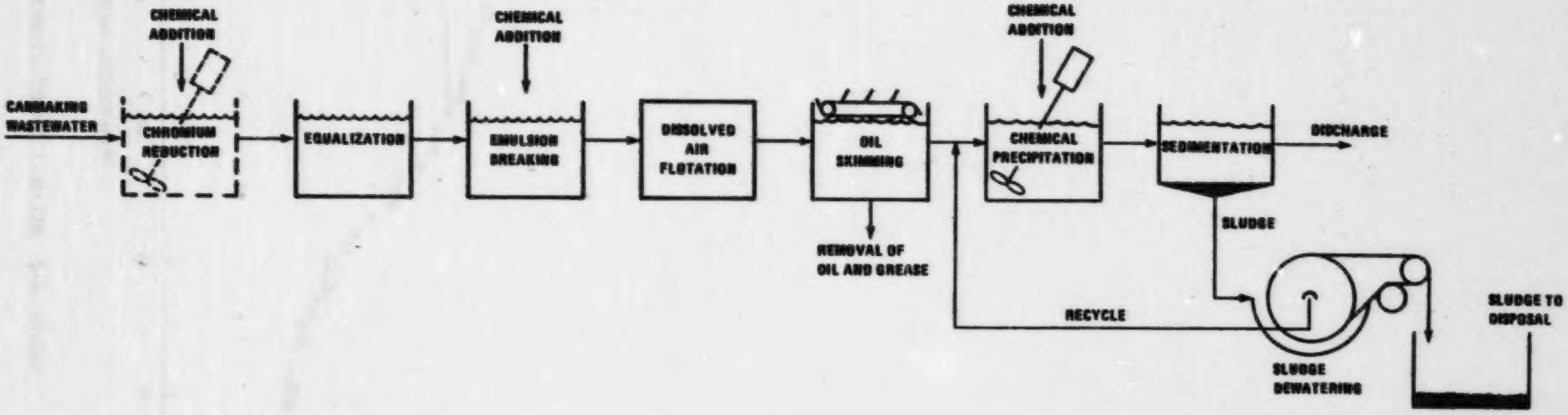

CANMAKING WASTEWATER
CHEMICAL ADDITION
CHROMIUM REDUCTION
EQUALIZATION
CHEMICAL ADDITION
EMULSION BREAKING
DISSOLVED AIR FLOTATION
OIL SKIMMING
REMOVAL OF OIL AND GREASE
CHEMICAL ADDITION
CHEMICAL PRECIPITATION
SEDIMENTATION
DISCHARGE
SLUDGE
RECYCLE
SLUDGE DEWATERING
SLUDGE TO DISPOSAL

FIGURE IX-1. BPT WASTEWATER TREATMENT SYSTEM

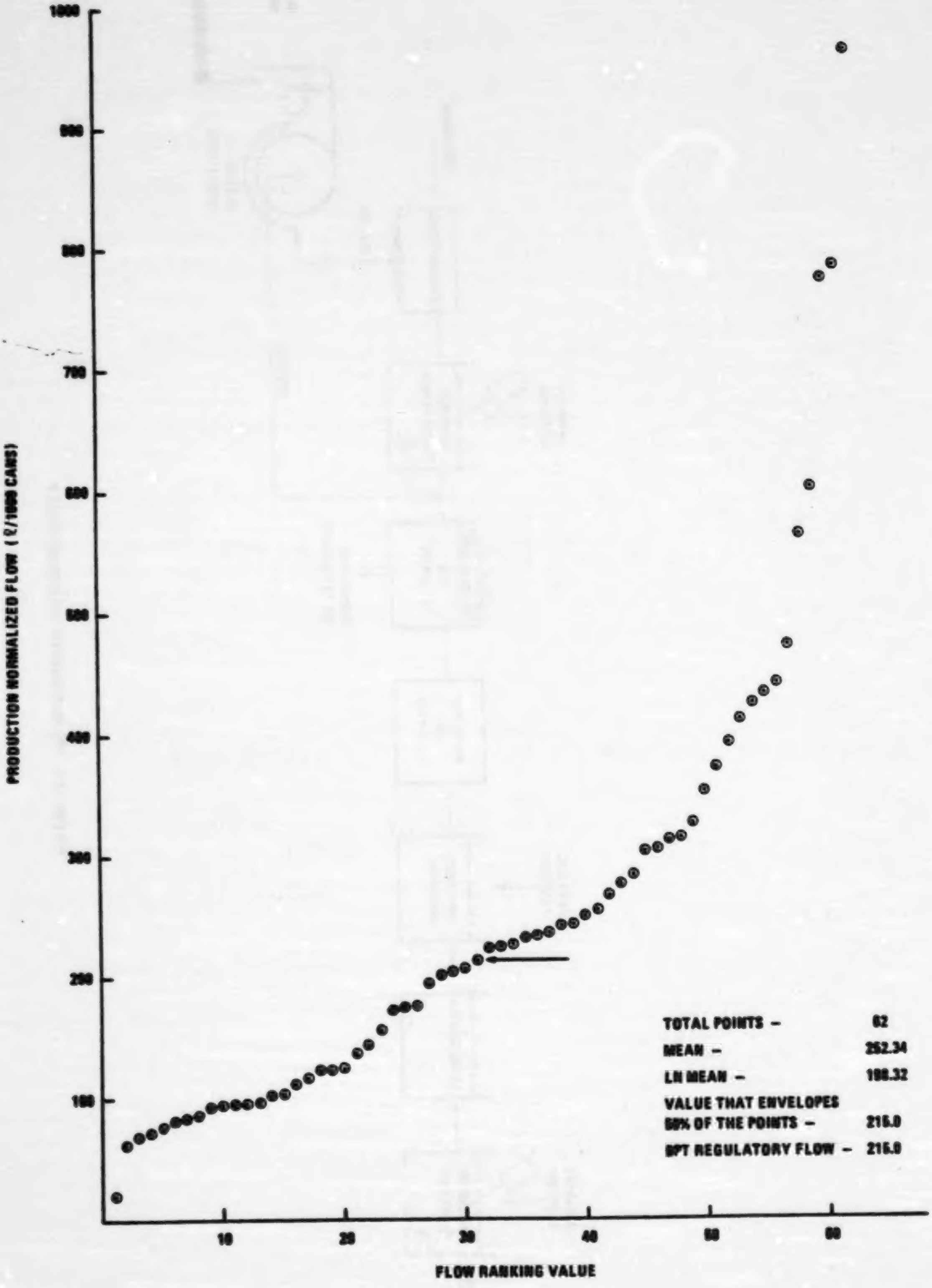


FIGURE IX-2. ALL USABLE PRODUCTION NORMALIZED FLOW DATA

SECTION X

BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE

The effluent limitations in this section apply to existing direct dischargers. A direct discharger is a facility which discharges or may discharge pollutants into waters of the United States. This section presents information on direct dischargers, and in addition presents total subcategory data.

The factors considered in assessing the best available technology economically achievable (BAT) include the age of equipment and facilities involved, the processes employed, process changes, nonwater quality environmental impacts (including energy requirements) and the costs of application of such technology (CWA Section 304(b)(2)(B)). BAT technology represents the best existing economically achievable performance of plants of various ages, sizes, processes or other shared characteristics. As with BPT, those categories whose existing treatment system performance is inadequate may require a transfer of BAT from a different subcategory or category. BAT may include process changes or internal controls, even when these are not common industry practice.

TECHNICAL APPROACH TO BAT

In establishing BAT limitations, the Agency reviewed a wide range of technology options. These options included the range of available technologies applicable to the subcategory.

In the proposed regulation for the subcategory, three levels of BAT which accomplish reduction in the discharge of toxic pollutants greater than that achieved at BPT were evaluated.

The Agency proposed BAT limitations based on the following treatment technologies:

- reduction of hexavalent chromium, when necessary
- precipitation of cyanide when necessary
- removal of oil by skimming, chemical emulsion breaking, and dissolved air flotation
- hydroxide precipitation and sedimentation of metals
- water reuse
- two-stage countercurrent cascade spray rinse following conversion coating in the canwasher
- sludge dewatering

The proposed BAT limitations were presented as BAT Option 1, which included all of the treatment technologies described above. BAT Option 2 included all the treatment and flow reduction technologies of Option 1 plus filtration. At proposal, BAT Option 3 included all the treatment and flow reduction technologies of Option 1 plus ultrafiltration. The schematic diagrams of these systems are presented in Figures X-1 through X-3 (pages 337 to 339).

The Agency received comments criticizing the requirement of countercurrent cascade rinsing at BAT. Industry believed that this flow reduction technology was not fully demonstrated and would not achieve the proposed BAT flow. In response to these and other comments, the Agency reevaluated the flow reduction basis for BAT. While at least three plants are known to use countercurrent cascade rinsing and can be used to achieve the BAT flow, the model flow reduction technology basis for the final BAT regulation is counterflow rinsing, which is demonstrated at fourteen plants. For the purposes of establishing a BAT flow in the final regulation, counterflow rinsing is defined as having all of the makeup water for stage 3 (the rinse following can etching or cleaning) taken from the overflow of stage 5 (the rinse following metal surface treatment).

BAT OPTION SELECTION

The final BAT limitations are based on BAT Option 1 which consists of: flow reduction using counterflow rinsing; removal of oil and grease using skimming, chemical emulsion breaking, or dissolved air flotation, or a combination of these technologies; chromium reduction where necessary; and removal of other pollutants using lime and settle technology. Cyanide precipitation is not included in the final model end-of-pipe treatment technology for the reasons presented in Section IX.

Using the methodology described later in this section, the Agency determined that the selected BAT (Option 1) will remove 135 kg/yr of toxic pollutants incrementally over the pollutant removal achieved by BPT. BAT Option 2 achieves little incremental removal of toxic pollutants beyond BAT Option 1 (25.5 kg/yr of toxic pollutants over BAT Option 1) as calculated on a model plant basis (See Table X-2, page 332), at an additional capital cost of $0.017 million and an additional annual cost of $0.011 million. BAT Option 3 was rejected for the same reasons. As a result, these options were not selected for the canmaking subcategory. The economic impact analysis indicates that the selected BAT option is economically achievable.

Industry Cost and Effluent Reduction Benefits of Treatment Options

The capital and annual costs for the selected BAT were estimated using the methodology in Section VIII. The capital costs take into account treatment currently in place. Annual costs reflect the operation of the entire treatment system, including equipment in place, and account for capital recovery. Capital and annual costs for BAT-1 and BAT-2 were also estimated for a normal plant. Results are presented in Table X-5 (page 335).

Pollution reduction benefits were derived by: (a) characterizing untreated (raw) wastewater and treated effluent from each treatment option in terms of pollutant concentration and production normalized mass (Table X-1, page 331) for each pollutant considered for regulation; (b) calculating the quantities of pollutants removed and discharged annually by a normal plant in the subcategory (Table X-2, page 332); (c) calculating the quantities removed and discharged annually by the subcategory (Table X-3, page 333); and (d) calculating the pollutant reduction benefits for existing direct dischargers (Table X-4, page 334). Pollutant reduction benefits for indirect dischargers are presented in Table XII-3, page 360. All pollutant parameter calculations were based on mean raw wastewater concentrations for plants sampled by EPA before proposal (Table V-11, page 65).

REGULATED POLLUTANT PARAMETERS

The raw wastewater concentrations from individual operations were examined to select appropriate pollutant parameters for specific regulation. In Section VI each of the toxic pollutants was evaluated and a determination was made as to whether or not to further consider them for regulation. Pollutants were not considered for regulation if they were not detected, detected at nonquantifiable levels, or not treatable using technologies considered appropriate for this subcategory. All toxic and nonconventional pollutants considered are discussed in this Section. The pollutant parameters selected for BAT regulation in the canmaking subcategory are: chromium, zinc, aluminum, fluoride, and phosphorus.

Comments were received after proposal that toxic organic pollutants had been eliminated from canmaking operations by recent changes in canmaking technology. Effluent sampling data collected by EPA and by industry do not bear out this claim. Several toxic organic compounds (collectively referred to as total toxic organics or TTO) were found in canmaking wastewaters. These include seven specific compounds which were identified prior to proposal at concentrations greater than the quantification level of 0.01 mg/l (see Table V-11, page 65) and seven additional compounds which were identified following proposal (see Table V-10, page 64, Table V-19, page 84 and Table

V-21, page 86). See also Table XII-2, page 359 for a complete listing.

The percent removal of organics by oil skimming from aluminum forming plants is presented in Section VII. The average removal of organics in aluminum forming by oil skimming is about 97 percent. This removal rate is used for projecting the effectiveness of the model oil removal technology in removing TTO in canmaking, because some of the lubricants from forming are carried into the canmaking operation and the raw wastewater levels of oil in canmaking and aluminum forming are similar (see Section IX for a more detailed discussion). Many of the toxic organic pollutants found in canmaking are found in coil coating, aluminum forming, or copper forming and have been shown to be removed by oil removal. TTO is not regulated at BAT because it is incidentally removed by oil and grease removal technology which is required to be installed by BPT limitations for oil and grease and by BCT limitations that should be included in NPDES permits.

The toxic metals selected for specific BAT regulation are total chromium and zinc. Hexavalent chromium is not regulated specifically because it is included in total chromium. Only the trivalent form is removed by the lime and settle technology. Therefore, when present, the hexavalent form must be reduced to meet the limitation on total chromium. Copper, lead, nickel, and manganese are not regulated because they will be adequately removed by the model technology when it is operated to remove the other regulated pollutants.

Aluminum is regulated at BAT primarily because it is frequently present in high concentrations in canmaking wastewaters, can adversely affect receiving waters at these concentrations, and assures the removal of other toxic pollutants.

Fluoride and phosphorus are regulated at BAT because they are routinely used in process chemicals in canmaking operations; they are commonly found in canmaking wastewaters; they can adversely affect receiving waters; and their control will help assure the proper operation of lime and settle technology.

Proper pH control is essential to optimal operation of lime and settle treatment systems for removing regulated metals, fluoride and phosphorus. While pH is a conventional pollutant parameter designated by the Clean Water Act and is therefore not regulated at BAT, the BPT limitations for pH remain in effect and ensure proper control.

CANMAKING SUBCATEGORY BAT

BAT Flow Calculation

The BAT flow of 83.9 l/1000 cans was based on the flow reductions achieved at a number of plants using counterflow rinsing. For the purposes of this regulation, counterflow rinsing is defined as having all of the make-up water for stage three (the rinse following can etching or cleaning) taken from the overflow from stage five (the rinse following metal surface treatment). This flow reduction technique is discussed in Sections III and VII and is known to be used at fourteen plants. Because of plant specific anomalies at two plants (Plants 578 and 692), twelve of these fourteen plants were used as the data base for determining the BAT flow (see Figure X-4, page 340). The BAT flow was based on the performance of the median plant among the twelve plants without anomalies which practice counterflow rinsing as defined above. The BAT flow for canmaking is thus 83.9 l/1000 cans, which is 60 percent below the BPT regulatory flow allowance.

Prior to establishing this BAT flow, the Agency considered thirteen specific factors which commenters presented as possible barriers to the achievement of the BAT flow. These factors are presented and discussed in detail in Section IX. For the same reasons presented in that Section, the Agency has determined that none of these factors will prevent the achievement of the BAT flow by any plant.

The BAT flow is presently being achieved by six plants using counterflow rinsing techniques (see Table V-2, page 54). Moreover, other flow reduction techniques, including countercurrent cascade rinsing, recycle following end-of-pipe treatment, and water conservation practices can achieve similar reductions in flow. One additional plant presently achieves the BAT flow using various combinations of these techniques plus ultrafiltration and reverse osmosis. The BAT flow is achievable by each plant in the subcategory.

BAT Effluent Limitations Calculation

The BAT model end-of-pipe treatment technology will achieve the effluent concentrations of regulated pollutants shown in Section VII, Table VII-21 for lime and settle technology. The Agency determined the expected pollutant concentrations in waste streams following the BAT flow reduction (see Table X-1), and compared these expected concentrations to the raw wastewater concentrations of pollutants in the combined metals data base (CMDB). The range of these expected concentrations is within the raw waste concentrations in plants in the CMDB and in other categories used to establish treatment effectiveness, thus showing that the treated effluent concentrations used in this regulation can be achieved by canmaking plants after the application of BAT flow reduction. The CMDB and the elements of the BAT end-of-pipe treatment technology are described in detail in Section VII, and Section IX presents the rationale for establishing the treatment effectiveness of the model end-of-pipe technology in the canmaking subcategory.

When these concentrations are applied to the BAT flow of 83.9 l/1000 cans, the mass of pollutant allowed to be discharged per million cans produced can be calculated. Table X-6, page 336, shows the limitations derived from this calculation. The pollutants listed as "considered for regulation" in Table VI-1, but for which a regulation is not promulgated, will be adequately removed coincidentally if the regulated pollutants are removed to the specified levels.

DEMONSTRATION STATUS

Each element of the BAT system is demonstrated; however, no sampled canmaking plants use the BAT technology in its entirety. The BAT model system has the same end-of-pipe treatment as BPT and five plants have all elements of the model end-of-pipe treatment equipment in place. Data supplied by the canmaking companies in their dcp responses indicate that seven plants achieve the BAT flow, including six that achieve the BAT flow using counterflow rinsing. The flow reduction and end-of-pipe treatment technologies are both demonstrated.

TABLE X-1
SUMMARY OF TOTAL TREATMENT EFFECTIVENESS
CANMAKING SUBCATEGORY (BPT, BAT, & PSES)

PARAMETER	RAW WASTE		BPT(PSES-0) RAW		BPT(PSES-0) TREATED		BAT(PSES) RAW		BAT-1(PSES-1) TREATED		BAT-2(PSES-2) TREATED	
	mg/1	mg/10^3 cans	mg/1	mg/10^3 cans	mg/1	mg/10^3 cans	mg/1	mg/10^3 cans	mg/1	mg/10^3 cans	mg/1	mg/10^3 cans
Flow, 1/10^3 cans		252.34				215.0				83.9		83.9
Chromium	1.01	253.85	1.18	253.85	0.08	18.06	3.03	253.85	0.08	7.05	0.07	5.87
Copper	0.04	9.59	0.04	9.59	0.04	9.59	0.11	9.59	0.11	9.59	0.15	12.59
Lead	0.03	7.57	0.04	7.57	0.04	7.57	0.09	7.57	0.09	7.57	0.08	6.71
Nickel	0.18	44.66	0.21	44.66	0.21	44.66	0.53	44.66	0.53	44.66	0.22	18.46
Zinc	0.92	233.16	1.08	233.16	0.33	70.95	2.78	233.16	0.33	27.69	0.23	19.30
Aluminum	138.30	34898.62	162.32	34898.62	2.24	481.60	415.95	34898.62	2.24	187.94	1.49	125.01
Fluoride	16.74	4224.17	19.65	4224.17	14.50	3117.50	50.35	4224.17	14.50	1216.55	14.50	1216.55
Iron	1.40	352.52	1.64	352.52	0.41	88.15	4.20	352.52	0.41	34.40	0.28	23.49
Manganese	1.85	467.08	2.17	467.08	0.16	34.40	5.57	467.08	0.16	13.42	0.14	11.75
Phosphorus	6.06	1529.18	7.11	1529.18	4.08	877.20	18.23	1529.18	4.08	342.31	2.72	228.21
Oil & Grease	6596.00	1.66×10^6	7741.56	1.66×10^6	10.00	2150.00	19828.32	1.66×10^6	10.00	839.00	10.00	839.00
TSS	471.00	118852.14	552.80	118852.14	12.00	2580.00	1416.59	118852.14	12.00	1006.80	2.60	218.14
TTO	2.73	688.89	3.20	688.89	0.10	20.67	8.21	688.89	0.25	20.67	0.32	26.85

TABLE X-2

POLLUTANT REDUCTION BENEFITS OF CONTROL SYSTEMS - NORMAL PLANT

PARAMETER	RAW WASTE	BPT & PSES-0		BAT-1 & PSES-1		BAT-2 & PSES-2	
	kg/yr	Removed kg/yr	Discharged kg/yr	Removed kg/yr	Discharged kg/yr	Removed kg/yr	Discharged kg/yr
Flow, $1/10^3$ cans			215.0		83.9		83.9
Flow, 10^6 1/yr	175.65		149.66		58.40		58.40
Chromium	176.70	164.13	12.57	171.79	4.91	172.61	4.09
Copper	6.67	0.00	6.67	0.00	6.67	0.00	6.67
Lead	5.27	0.00	5.27	0.00	5.27	0.60	4.67
Nickel	31.09	0.00	31.09	0.00	31.09	18.24	12.85
Zinc	162.30	112.91	49.39	143.03	19.27	148.87	13.43
Aluminum	24292.40	23957.16	335.24	24161.57	130.82	24205.38	87.02
Fluoride	2940.38	770.31	2170.09	2093.58	846.80	2093.58	846.80
Iron	245.38	184.02	61.36	221.44	23.94	229.03	16.35
Manganese	325.13	301.18	23.94	315.79	9.34	316.95	8.18
Phosphorus	1064.44	453.83	610.61	826.17	238.27	905.59	158.85
Oil & Grease	1.16×10^6	1.16×10^6	1496.60	1.16×10^6	584.00	1.16×10^6	584.00
TSS	82731.15	80935.23	1795.92	82030.35	700.80	82579.31	151.84
TTO	479.52	467.25	12.27	474.73	4.79	474.73	4.79
Total Toxics	861.56	744.29	117.26	789.55	72.00	815.05	46.50
Total Other	1.27×10^6	1.26×10^6	6493.76	1.27×10^6	2533.99	1.27×10^6	1853.03
Total Conventionals	1.24×10^6	1.24×10^6	3292.53	1.24×10^6	1284.86	1.24×10^6	735.84
Sludge			6.86×10^6		6.94×10^6		

TABLE X-3
POLLUTANT REDUCTION BENEFITS OF CONTROL SYSTEMS - TOTAL SUBCATEGORY

PARAMETER	RAW WASTE	BPT(PSES-0)		BAT-1 (PSES-1)	
	kg/yr	Removed kg/yr	Discharged kg/yr	Removed kg/yr	Discharged kg/yr
Flow, $1/10^3$ cans			215.0		83.9
Flow, 10^6 l/yr	14578.95		12421.90		4847.42
Chromium	14666.47	13622.98	1043.43	14259.23	407.19
Copper	554.00	0.00	554.00	0.00	554.00
Lead	437.37	0.00	437.37	0.00	437.37
Nickel	2580.47	0.00	2580.47	0.00	2580.47
Zinc	13470.95	9371.73	4099.22	11871.29	1599.65
Aluminum	$2.01\text{x}10^6$	$1.99\text{x}10^6$	27825.66	$2.00\text{x}10^6$	10858.22
Fluoride	244051.62	63934.07	180117.55	173764.03	70287.59
Iron	20366.79	15273.81	5092.98	18379.35	1987.44
Manganese	26985.63	24998.12	1987.51	26210.04	775.59
Phosphorus	88348.44	37667.09	50681.35	68570.96	19777.48
Oil & Grease	$96.2\text{x}10^6$	$96.1\text{x}10^6$	124219.00	$96.1\text{x}10^6$	48474.20
TSS	$6.87\text{x}10^6$	$6.71\text{x}10^6$	149062.80	$6.81\text{x}10^6$	58169.04
TTO	39800.53	38781.93	1018.60	39403.04	397.49
Total Toxics	71509.75	61777.64	9733.09	65533.57	5976.17
Total Other	$106\text{x}10^6$	$105\text{x}10^6$	538986.25	$105\text{x}10^6$	210329.56
Total Conventionals	$103\text{x}10^6$	$103\text{x}10^6$	273281.80	$103\text{x}10^6$	106643.24
Sludge			$572\text{x}10^6$		$576\text{x}10^6$

TABLE X-4

POLLUTANT REDUCTION BENEFITS OF CONTROL SYSTEMS - DIRECT DISCHARGERS

PARAMETER	RAW WASTE	BPT		BAT - 1	
	kg/yr	Removed kg/yr	Discharged kg/yr	Removed kg/yr	Discharged kg/yr
Flow, 1/10^3 cans			215.0		83.9
Flow, 10^6 1/yr	526.95		448.98		175.20
Chromium	530.11	492.40	37.71	515.39	14.72
Copper	20.02	0.00	20.02	0.00	20.02
Lead	15.81	0.00	15.81	0.00	15.81
Nickel	93.27	0.00	93.27	0.00	93.27
Zinc	486.90	338.74	148.16	429.08	57.82
Aluminum	72877.18	71871.46	1005.72	72484.73	392.45
Fluoride	8821.14	2310.93	6510.21	6280.74	2540.40
Iron	736.15	552.07	184.08	664.32	71.83
Manganese	975.38	903.54	71.84	947.35	28.03
Phosphorus	3193.32	1361.48	1831.84	2478.50	714.82
Oil & Grease	3.48x10^6	3.47x10^6	4489.80	3.47x10^6	1752.00
TSS	248193.45	242805.69	5387.76	246091.05	2102.40
TTO	1438.57	1401.75	36.82	1424.20	14.37
Total Toxics	2584.69	2233.89	351.79	2368.67	216.01
Total Other	3.81x10^6	3.79x10^6	19481.25	3.80x10^6	7601.93
Total Conventionals	3.72x10^6	3.71x10^6	9877.56	3.72x10^6	3854.40
Sludge			20.7x10^6		20.8x10^6

TABLE X-5
TREATMENT COSTS

OPTIONS*

	A		B		C	
	Capital	Total Annual	Capital	Total Annual	Capital	Total Annual
Direct Dischargers	0.743	0.645	0.646	0.594	NC	NC
Indirect Dischargers	24.29	18.10	21.27	17.13	NC	NC
Subcategory Total	25.03	18.74	21.92	17.72	NC	NC
Normal Plant	NC	NC	0.382	0.267	0.399	0.278

	D		E		F	
	Capital	Total Annual	Capital	Total Annual	Capital	Total Annual
Direct Dischargers	NC	NC	NC	NC	NC	NC
Indirect Dischargers	NC	NC	NC	NC	NC	NC
Subcategory Total	NC	NC	NC	NC	NC	NC
Normal Plant	NC	NC	0.493	0.301	0.528	0.321

NOTE: Costs are presented in 1982 dollars (millions) and are above treatment equipment in place.

NC - Not calculated after proposal.

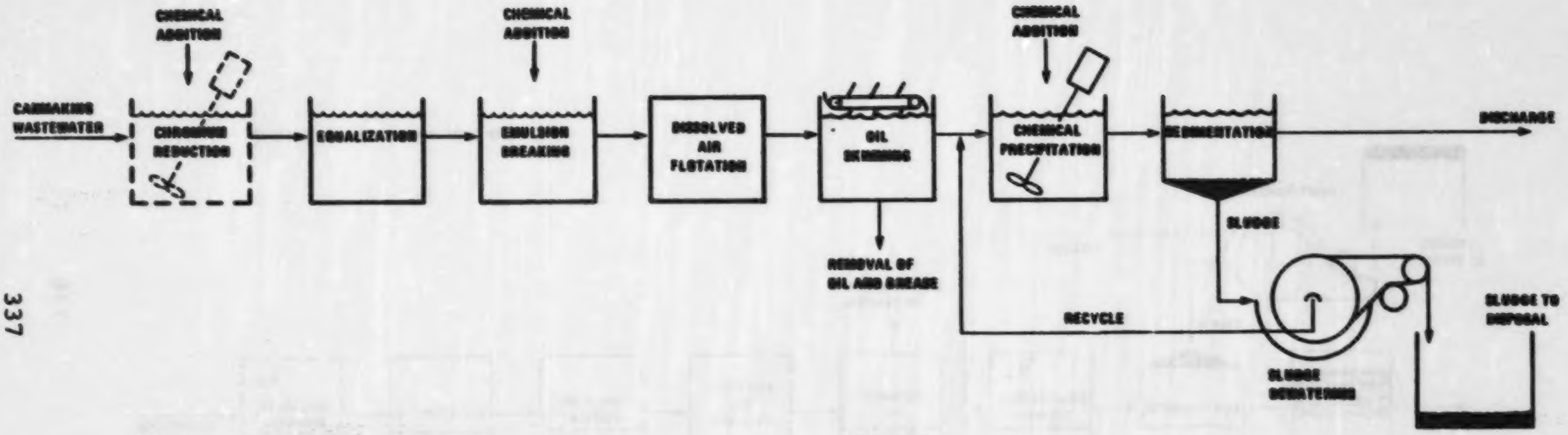
*Option A - Used for BPT, PSES-0
Option B - Used for BAT-1, PSES-1, NSPS-1, PSNS-1
Option C - Used for BAT-2, PSES-2, NSPS-2, PSNS-2
Option D - Used for BAT-3, PSES-3, NSPS-3, PSNS-3
Option E - Used for NSPS-4, PSNS-4
Option F - Used for NSPS-5, PSNS-5

TABLE X-6

BAT EFFLUENT LIMITATIONS
CANMAKING SUBCATEGORY

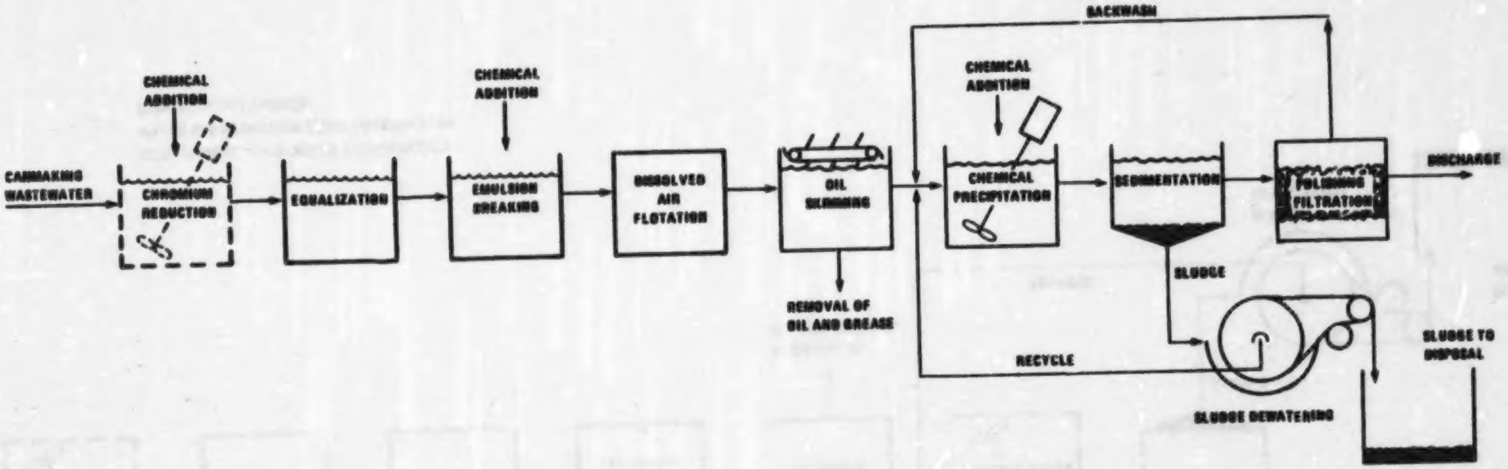
Pollutant or Pollutant Property	BAT Effluent Limitations			
	Maximum for any one day		Maximum for monthly average	
	g (lbs)/1,000,000 cans manufactured			
*Chromium	36.92	(0.081)	15.10	(0.033)
Copper	159.41	(0.351)	83.9	(0.185)
Lead	35.24	(0.078)	16.78	(0.037)
Nickel	161.09	(0.355)	106.55	(0.235)
*Zinc	122.49	(0.270)	51.18	(0.113)
*Aluminum	539.48	(1.189)	268.48	(0.592)
*Fluoride	4992.05	(11.001)	2214.96	(4.883)
Iron	100.68	(0.222)	51.18	(0.113)
Manganese	57.05	(0.126)	24.33	(0.054)
*Phosphorus	1401.13	(3.089)	573.04	(1.263)
Oil and Grease	1678.00	(3.700)	1006.8	(2.220)
TSS	3439.9	(7.584)	1636.05	(3.607)
TTO	26.85	(0.059)	12.59	(0.028)

*Regulated Pollutant


CHEMICAL ADDITION
CANMAKING WASTEWATER
CHROMIUM REDUCTION
EQUALIZATION
CHEMICAL ADDITION
EMULSION BREAKING
DISSOLVED AIR FLOTATION
OIL SKIMMING
REMOVAL OF OIL AND GREASE
CHEMICAL ADDITION
CHEMICAL PRECIPITATION
SEDIMENTATION
DISCHARGE
SLUDGE
RECYCLE
SLUDGE DEWATERING
SLUDGE TO DISPOSAL

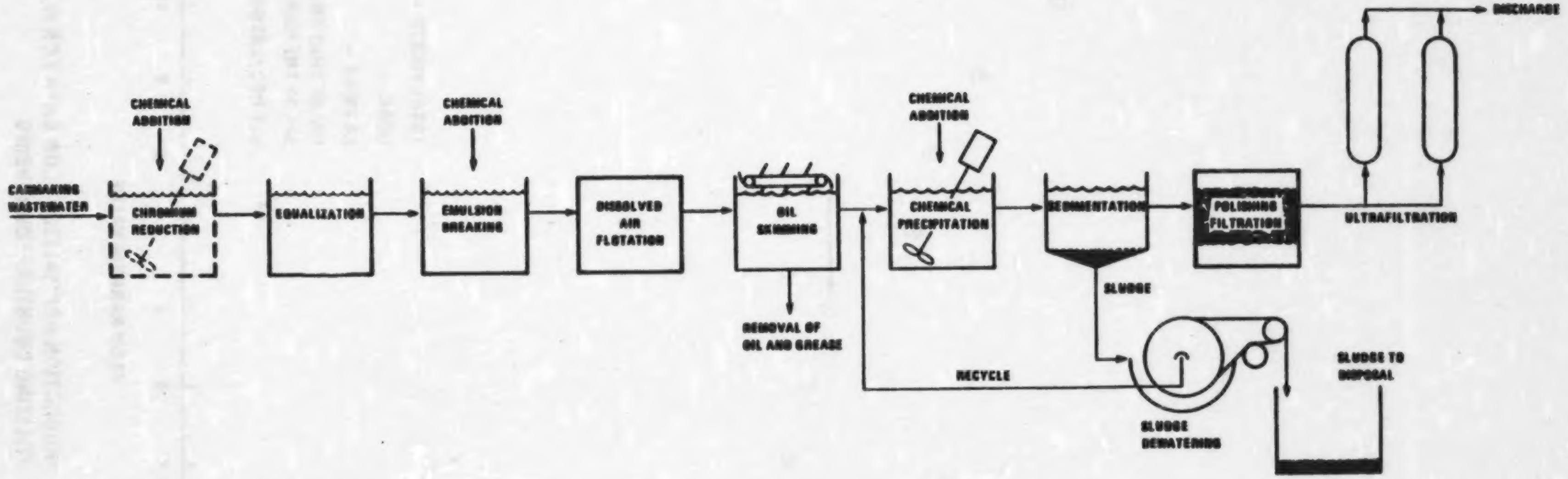
ADDITIONAL IN-PROCESS TECHNOLOGY:
WATER USE REDUCTION USING COUNTERFLOW
RINSING IN CAN WASHER.

FIGURE X-1. BAT LEVEL 1 WASTEWATER TREATMENT SYSTEM


CANMAKING WASTEWATER
CHEMICAL ADDITION
CHROMIUM REDUCTION
EQUALIZATION
CHEMICAL ADDITION
EMULSION BREAKING
DISSOLVED AIR FLOTATION
OIL SKIMMING
REMOVAL OF OIL AND GREASE
BACKWASH
CHEMICAL ADDITION
CHEMICAL PRECIPITATION
SEDIMENTATION
SLUDGE
POLISHING FILTRATION
DISCHARGE
RECYCLE
SLUDGE DEWATERING
SLUDGE TO DISPOSAL

ADDITIONAL IN-PROCESS TECHNOLOGY: NONE

FIGURE X-2. BAT LEVEL 2 WASTEWATER TREATMENT SYSTEM


CANMAKING WASTEWATER
CHEMICAL ADDITION
CHROMIUM REDUCTION
EQUALIZATION
CHEMICAL ADDITION
EMULSION BREAKING
DISSOLVED AIR FLOTATION
OIL SKIMMING
REMOVAL OF OIL AND GREASE
CHEMICAL ADDITION
CHEMICAL PRECIPITATION
RECYCLE
SEDIMENTATION
SLUDGE
SLUDGE DEWATERING
POLISHING FILTRATION
SLUDGE TO DISPOSAL
ULTRAFILTRATION
DISCHARGE

ADDITIONAL IN-PROCESS TECHNOLOGY: NONE

FIGURE X-3. BAT LEVEL 3 WASTEWATER TREATMENT SYSTEM

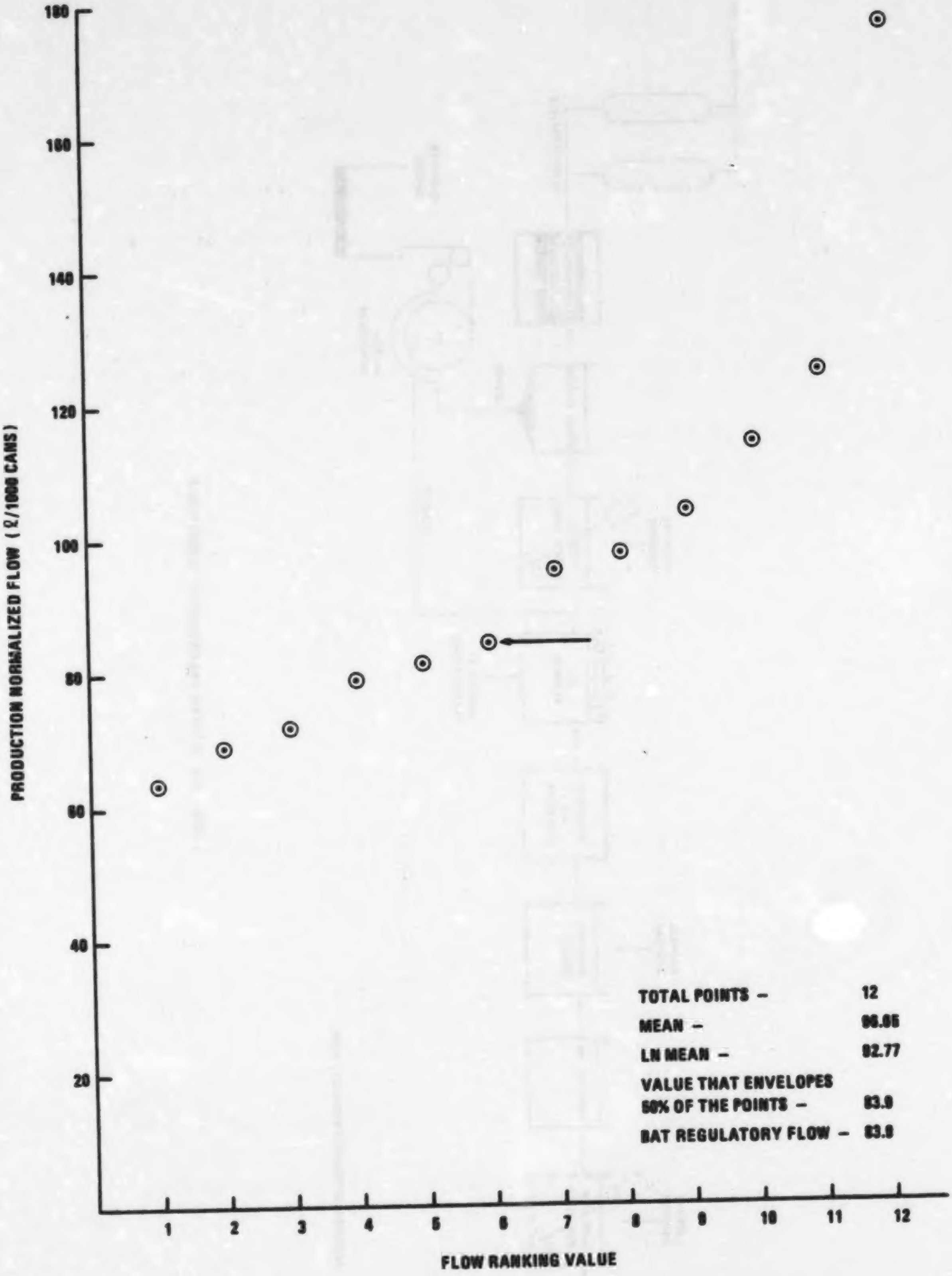


FIGURE X-4. PRODUCTION NORMALIZED FLOW DATA FOR PLANTS UTILIZING COUNTERFLOW RINSING

SECTION XI
NEW SOURCE PERFORMANCE STANDARDS

This section presents effluent characteristics attainable by new sources through the application of the best available demonstrated control technology, processes, operating methods, or other alternatives, including where practicable, a standard permitting no discharge of pollutants. Possible model NSPS technologies are discussed with respect to costs, performance, and effluent reduction benefits. The rationale for selecting one of the technologies is outlined. The selection of pollutant parameters for specific regulation is discussed, and discharge limitations for the regulated pollutants are presented.

TECHNICAL APPROACH TO NSPS

In the proposed regulation, five NSPS options were evaluated. The options were identical to or built on BAT technology options. The BAT options and the discussion and evaluation of them carried out in Section X are incorporated here by specific reference rather than repeated in this section.

NSPS Options 1, 2 and 3 presented at proposal were identical to BAT Options 1, 2 and 3 respectively, which are described in Section X. The schematic diagrams of those systems are presented in Figures X-1 through X-3. Schematic diagrams of NSPS Options 4 and 5 are presented in Figure XI-1, page 350, and Figure XI-2, page 351, respectively. In summary form, the two additional NSPS treatment options were:

NSPS Option 4:

- additional in-process water use reduction achievable by addition of three additional stages to a six-stage canwasher or its equivalent
- end-of-pipe treatment (identical to NSPS Option 1)
    - chromium reduction, when required
    - cyanide removal, when required
    - oil removal by chemical emulsion breaking, dissolved air flotation, oil skimming, or a combination of these technologies
    - lime precipitation
    - Stokes' law sedimentation

NSPS Option 5: All of NSPS Option 4 plus end-of-pipe polishing filtration.

An option requiring no discharge of process wastewater pollutants was also considered at proposal. One plant was believed to be achieving this level of pollutant reduction using water use reduction, ultrafiltration, reverse osmosis, and water reuse, although this plant was subsequently found to discharge at the rate of 2.36 l/1000 cans. This system for pollutant reduction is costly; investment costs greater than $1.7 million and annual costs greater than $0.97 million are projected for a new canmaking plant. This option is not considered as the basis for NSPS because of the high costs associated with this technology.

The Agency received comments criticizing the flow reductions achievable by the addition of three stages to a six-stage canwasher, which was the principal proposed flow basis for NSPS Options 4 and 5. Industry believed that this flow reduction technology was not fully demonstrated and would not achieve the proposed NSPS flow. In response to these and other comments, the Agency reevaluated the flow reduction basis for NSPS. As a result, the NSPS flow in the final regulation is based on the lowest demonstrated plant flow which is generally applicable in the subcategory. This flow is achieved by using counterflow rinsing and other water flow reduction techniques.

NSPS OPTION SELECTION

The final NSPS are based on NSPS Option 4, which consists of: flow reduction using counterflow rinsing and other techniques to achieve the lowest plant flow which is generally applicable in the subcategory; removal of oil and grease using skimming, chemical emulsion breaking, or dissolved air flotation, or a combination of these technologies; chromium reduction where necessary; and removal of other pollutants using lime and settle technology. Cyanide precipitation is not included in the final model end-of-pipe treatment technology for the reasons presented in Section IX.

Using the methodology described in Section VIII and later in this Section, EPA estimates that a new direct discharge canmaking plant having the industry average annual production level would generate a raw waste of 862 kg/yr of toxic pollutants. NSPS Option 4 would reduce these toxic pollutants to 65 kg/yr. In contrast, NSPS Options 1, 2, and 5 would result in the discharge of 72, 47, and 37 kg/yr of toxic pollutants, respectively. Options 1, 2 and 3 were not selected because Option 4 provides greater removal of pollutants and is economically achievable. Option 5 was not selected because the addition of filtration to the small effluent flow would achieve little additional toxic pollutant reduction.

EPA selected the final NSPS because it provides a reduced discharge of all pollutants below the final BAT (compare Table XI-1 with Table X-1). NSPS Option 5 achieves little incremental removal of pollutants beyond NSPS Option 4 (26.4 kg/yr of toxic pollutants as calculated for a normal plant, at an additional capital cost of $0.017 and an additional annual cost of $0.009 million). The Agency has determined that the new source performance standards will not pose a barrier to entry.

REGULATED POLLUTANT PARAMETERS

The raw wastewater concentrations from individual operations were examined to select appropriate pollutant parameters for specific regulation. In Section VI each of the toxic pollutants was evaluated and a determination was made as to whether or not to consider them further for regulation. Pollutants were not considered for regulation if they were not detected, detected at nonquantifiable levels, or not treatable using technologies considered. The pollutant parameters selected for NSPS regulation in the canmaking subcategory are: oil and grease, TSS, chromium, zinc, aluminum, fluoride, phosphorus, and pH.

Each of these pollutant parameters is discussed in detail in Sections IX and X and those discussions are incorporated here by reference. Further information may also be found in Section VI.

In addition to the pollutant parameters listed above, there is some amount of toxic organic pollutants in the canmaking wastewaters. The Agency is establishing an oil and grease standard for new sources in order to control the oil soluble organics found in these wastewaters. Although a specific numeric standard for organic priority pollutants is not established, adequate control is expected to be achieved by control of the oil and grease wastes. This is projected to occur because of the slight solubility of the compounds in water and their relatively high solubility in oil. This difference in solubility will cause the organics to accumulate in and be removed with the oil (See Tables VII-12, VII-13, and VII-29, pages 223, 224, and 235), and see the discussion in Section X).

Other pollutants are also found in canmaking wastewaters, including copper, nickel, lead, and manganese. These pollutants are not regulated specifically because the Agency determined that they would be removed coincidentally with other pollutants when the model end-of-pipe treatment system is employed and properly operated.

CANMAKING SUBCATEGORY NSPS

Calculation of NSPS Flow and Effluent Limitations

The NSPS regulatory wastewater flow for the canmaking subcategory is 63.6 l/1000 cans. This regulatory flow is based on the lowest demonstrated plant flow which is generally applicable in the subcategory and represents a 70% reduction from the BPT regulatory flow. This flow is based on the demonstrated performance of Plant 555, which utilizes counterflow rinsing and other water conservation practices to achieve this flow. These practices and techniques are described in Sections III and VII. This flow is also achievable by countercurrent cascade rinsing techniques, as described in Section VII.

Plant 438 achieves a lower plant flow than the NSPS flow: 2.36 l/1000 cans in actual operation or 20.3 l/1000 cans when unique in-plant water reuse practices are factored out. This plant was not used as the basis for NSPS since the plant was not considered to be generally applicable to the subcategory.

Prior to establishing this NSPS flow, the Agency considered thirteen specific factors which commenters presented as possible barriers to the achievement of the NSPS flow. These factors are presented and discussed in detail in Section IX. For the same reasons presented in that section, the Agency has determined none of these factors will prevent the achievement of the NSPS flow by any plant.

Pollutant parameters selected for regulation for NSPS are: chromium, zinc, aluminum, fluoride, phosphorus, oil and grease, TSS, and pH. The NSPS end-of-pipe treatment technology will achieve the effluent concentrations of regulated pollutants equal to those shown in Section VII, Table VII-21 for lime and settle technology. pH must be maintained within the range 7.0 - 10.0 at all times.

The Agency determined the expected pollutant concentrations in waste streams following the NSPS flow reduction and compared these expected concentrations to the raw wastewater (see Table XI-1, page 347) concentrations of pollutants in the combined metals data base. The range of these expected concentrations is within the raw waste concentrations in plants in the CMDB and in other categories used to establish treatment effectiveness, thus showing that the treated effluent concentrations used in this regulation can be achieved by canmaking plants after the application of NSPS flow reduction. The CMDB and the elements of the NSPS end-of-pipe treatment technology are described in detail in Section VII, and Section IX presents the rationale for establishing the treatment effectiveness of the model end-of-pipe technology in the canmaking subcategory.

When these concentrations are applied to the water use described above, the mass of pollutant allowed to be discharged per 1,000,000 cans produced can be calculated. Table XI-3, page 349, shows the standards derived from this calculation.

Cost and Effluent Reduction Benefits of NSPS

In calculating NSPS costs, the production from a 696 million cans/yr "normal plant" was multiplied by the NSPS regulatory flow, to derive the plant flows for cost estimation. The added cost of pipes, pumps and other parts to achieve the NSPS flow was estimated. No plant-specific production or construction cost is included.

Because the technology on which the new source flow is based is the same as for BAT there would be no incremental cost above BAT. However, the Agency considered that some new sources might install additional technology to meet the new source flows. For a worst case evaluation the Agency considered that three additional stages of countercurrent cascade rinsing might be added beyond BAT. The total capital investment cost for a new model canmaking plant to install NSPS technology for a worst case situation is estimated to be $0.493 million, compared with investment costs of $0.382 million for a model plant to install technology equivalent to BAT. Similar figures for total annual costs are $0.302 million for NSPS, compared with $0.267 million for BAT. Thus, if the more expensive technology were used, NSPS investment and annual costs would be about ten percent greater than BAT costs for existing sources. These incremental costs for NSPS over BAT would represent less than 0.1 percent of expected revenues for a new source model plant. The Agency has determined that the new source performance standards will not pose a barrier to entry.

For costing, the proposed in-process costing model (installation of three additional stages to a six stage canwasher) was retained because plants can achieve the new source flow using this technique. There would be no additional costs above BAT for a new source to achieve NSPS using counterflow rinsing technology, which is used at the plant used as the basis for new sources.

The pollutant reduction benefit was derived by (a) characterizing untreated wastewater and effluent from each treatment system in terms of concentrations produced and production normalized discharges for each pollutant considered for regulation and (b) calculating the quantities removed and discharged annually by a "normal plant." Since NSPS apply to new sources, no treatment equipment in place is assumed. Results of these calculations are presented in Table XI-2 (page 348). All pollutant parameter calculations were based on mean raw wastewater concentrations for plants sampled by EPA before proposal (see Table V-11, page 65).

DEMONSTRATION STATUS

Each major element of the NSPS technology is demonstrated in one or more canmaking plants; however no sampled canmaking plant uses all of the NSPS technology. Plant 555, the plant which is the basis for the NSPS flow, lacks lime addition and oil removal technology.

The NSPS model system has all the same treatment components of the BAT model system plus further flow reduction. The NSPS flow is demonstrated at two plants (although one plant exhibits anomalies which prevent the applicability of its performance to the entire subcategory). As discussed in detail in Section IX, five plants have installed all elements of the model end-of-pipe treatment system and the treatment effectiveness of the model treatment system is confirmed by numerous data points within the canmaking subcategory (see Section IX). Therefore, NSPS technology is demonstrated in the subcategory.

TABLE XI-1
SUMMARY OF TREATMENT EFFECTIVENESS
CANMAKING SUBCATEGORY (NEW SOURCES)

PARAMETER	RAW WASTE		NSPS (PSNS) RAW		NSPS-4 (PSNS-4) TR[illegible]TED		NSPS-5 (PSNS-5) TREATED	
	mg/1	mg/10^3 cans	mg/1	mg/10^3 cans	mg/1	mg/10^3 cans	mg/1	mg/10^3 cans
Flow, 1/10^3 cans		252.34				63.6		63.6
Chromium	1.01	253.85	3.99	253.85	0.08	5.34	0.07	4.45
Copper	0.04	9.59	0.15	9.59	0.15	9.59	0.15	9.59
Lead	0.03	7.57	0.12	7.57	0.12	7.57	0.08	5.09
Nickel	0.18	44.66	0.70	44.66	0.70	44.66	0.22	13.99
Zinc	0.92	233.16	3.67	233.16	0.33	20.99	0.23	14.63
Aluminum	138.30	34898.62	548.72	34898.62	2.24	142.46	1.49	94.76
Fluoride	16.74	4224.17	66.42	4224.17	14.50	922.20	14.50	922.20
Iron	1.40	352.52	5.54	352.52	0.41	26.08	0.28	17.81
Manganese	1.85	467.08	7.34	467.08	0.16	10.18	0.14	8.90
Phosphorus	6.06	1529.18	24.04	1529.18	4.08	259.49	2.72	172.99
Oil & Grease	6596.00	1.66×10^6	26170.36	1.66×10^6	10.00	636.00	10.00	636.00
TSS	471.00	118852.14	1868.74	118852.14	12.00	763.20	2.60	165.36
TTO	2.73	688.89	10.83	688.89	0.32	20.67	0.32	20.67

TABLE XI-2

POLLUTANT REDUCTION BENEFITS OF CONTROL SYSTEMS - NORMAL PLANT (NEW SOURCES)

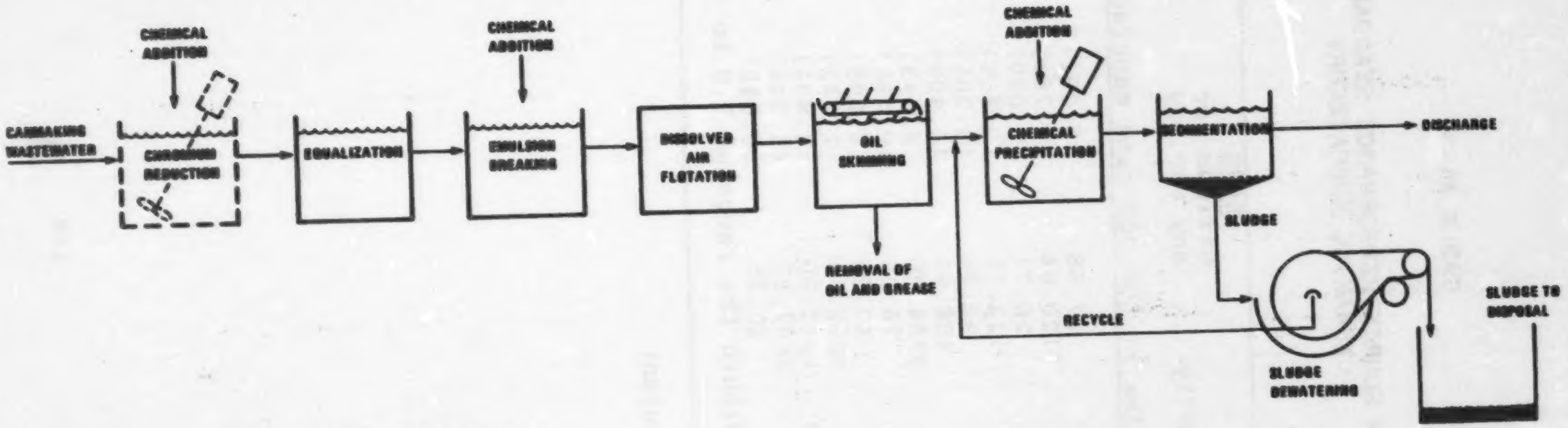
PARAMETER	RAW WASTE	NSPS-4 (PSNS-4)		NSPS-5 (PSNS-5)	
	kg/yr	Removed kg/yr	Discharged kg/yr	Removed kg/yr	Discharged kg/yr
Flow, $1/10^3$ cans	252.34		63.6		63.6
Flow, 10^6 l/yr	175.65		44.27		44.27
Chromium	176.70	172.98	3.72	173.60	3.10
Copper	6.67	0.00	6.67	0.00	6.67
Lead	5.27	0.00	5.27	1.73	3.54
Nickel	31.09	0.00	31.09	21.35	9.74
Zinc	162.30	147.69	14.60	152.11	10.18
Aluminum	24292.40	24193.24	99.16	24226.44	65.96
Fluoride	2940.38	2298.46	641.92	2298.46	641.92
Iron	245.38	227.23	18.15	232.98	12.40
Manganese	325.12	318.04	7.08	318.93	6.19
Phosphorus	1064.44	883.82	180.62	944.02	120.41
Oil & Grease	1.16×10^6	1.16×10^6	442.70	1.16×10^6	442.70
TSS	82731.15	82199.91	531.24	82616.05	115.10
TTO	479.52	475.89	3.63	475.89	3.63
Total Toxics	861.56	796.56	64.98	824.69	36.86
Total Other	1.27×10^6	1.27×10^6	1920.87	1.27×10^6	1404.69
Total Conventionals	1.24×10^6	1.24×10^6	973.94	1.24×10^6	557.80
Sludge			6.95×10^6		

TABLE XI-3

NEW SOURCE PERFORMANCE STANDARDS
CANMAKING SUBCATEGORY

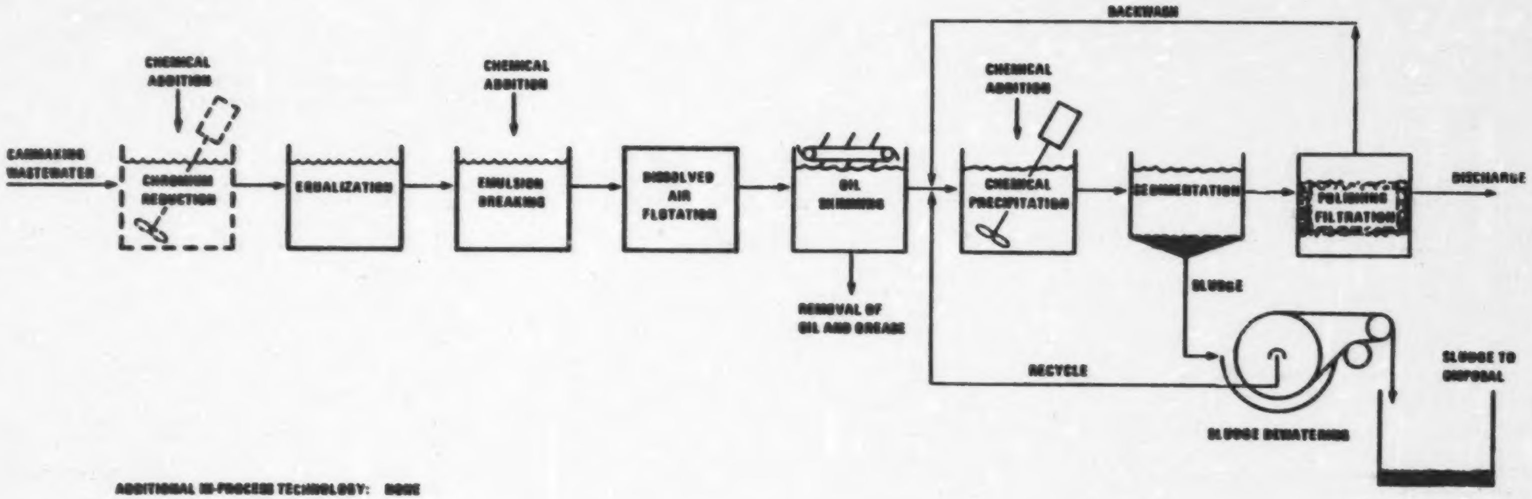
Pollutant or Pollutant Property	NSPS Maximum for any one day		Maximum for monthly average	
	g (lbs)/1,000,000 cans manufactured			
*Chromium	27.98	(0.062)	11.45	(0.025)
Copper	120.84	(0.266)	63.6	(0.140)
Lead	26.71	(0.059)	12.72	(0.028)
Nickel	122.11	(0.269)	80.77	(0.178)
*Zinc	92.86	(0.205)	38.80	(0.086)
*Aluminum	408.95	(0.902)	203.52	(0.449)
*Fluoride	3784.20	(8.343)	1679.04	(3.702)
Iron	76.32	(0.168)	38.80	(0.086)
Manganese	43.25	(0.095)	18.44	(0.041)
*Phosphorus	1062.12	(2.342)	434.39	(0.958)
*Oil and Grease	1272.00	(2.804)	763.20	(1.683)
*TSS	2607.60	(5.749)	1240.20	(2.734)
TTO	20.35	(0.045)	9.54	(0.021)
*pH	Within the range of 7.0 to 10 at all times			

*Regulated Pollutant


CANMAKING WASTEWATER
CHEMICAL ADDITION
CHROMIUM REDUCTION
EQUALIZATION
CHEMICAL ADDITION
EMULSION BREAKING
DISSOLVED AIR FLOTATION
OIL SKIMMING
REMOVAL OF OIL AND GREASE
CHEMICAL ADDITION
CHEMICAL PRECIPITATION
SEDIMENTATION
DISCHARGE
SLUDGE
RECYCLE
SLUDGE DEWATERING
SLUDGE TO DISPOSAL

ADDITIONAL IN-PROCESS TECHNOLOGY:
WATER USE REDUCTION USING COUNTERFLOW
RINSING, ADDITIONAL WATER REUSE, OR
EXTENDED MULTISTAGE CAN WASHER.

FIGURE XI-1. NSPS LEVEL 4 WASTEWATER TREATMENT SYSTEM


CANMAKING WASTEWATER
CHEMICAL ADDITION
CHROMIUM REDUCTION
EQUALIZATION
CHEMICAL ADDITION
EMULSION BREAKING
DISSOLVED AIR FLOTATION
OIL SKIMMING
REMOVAL OF OIL AND GREASE
BACKWASH
CHEMICAL ADDITION
CHEMICAL PRECIPITATION
SEDIMENTATION
POLISHING FILTRATION
DISCHARGE
SLUDGE
RECYCLE
SLUDGE DEWATERING
SLUDGE TO DISPOSAL

ADDITIONAL IN-PROCESS TECHNOLOGY: NONE

FIGURE XI-2. NSPS LEVEL 5 WASTEWATER TREATMENT SYSTEM

SECTION XII

PRETREATMENT STANDARDS

The model control technologies for pretreatment of process wastewaters from existing sources and new sources are described. An indirect discharger is defined as a facility which introduces pollutants into a publicly owned treatment works (POTW).

Pretreatment standards for existing sources (PSES) are designed to prevent the discharge of pollutants that pass through, interfere with, or are otherwise incompatible with the operation of publicly owned treatment works (POTW). They must be achieved within three years of promulgation. The Clean Water Act of 1977 requires pretreatment for pollutants that pass through the POTW in amounts that would violate direct discharger effluent limitations or interfere with the POTW's treatment process or chosen sludge disposal method.

The legislative history of the 1977 Act indicates that pretreatment standards are to be technology-based, analogous to the best available technology for removal of toxic pollutants. The general pretreatment regulations, which served as the framework for the pretreatment regulations, are found at 40 CFR Part 403. See 43 FR 27736 June 26, 1978, 46 FR 9404 January 28, 1981, and 47 FR 4518 February 1, 1982.

PSNS are to be issued at the same time as NSPS. New indirect dischargers, like new direct dischargers, have the opportunity to incorporate the best available demonstrated technologies. The Agency considers the same factors in promulgating PSNS as it considers in promulgating PSES.

Most POTW consist of primary or secondary treatment systems which are designed to treat domestic wastes. Many of the pollutants contained in canmaking wastes are not biodegradable and are therefore ineffectively treated by such systems. Furthermore, these wastes have been known to interfere with the normal operations of these systems. Problems associated with the uncontrolled release of pollutant parameters identified in canmaking process wastewaters to POTW were discussed in Section VI. The pollutant-by-pollutant discussions in that Section covered pass through, interference, and sludge usability.

EPA has generally determined there is pass through of pollutants if the percent of pollutants removed by a well operated POTW achieving secondary treatment is less than the percent removed by the BAT model treatment technology. POTW removals of the

Preceding page blank

priority pollutants found in canmaking wastewater are presented in Table XII-1 (page 358). The average removal of toxic metals is about 50 percent. The BAT treatment technology removes more than 92 percent of toxic metals (see Table X-2, page 332). This difference in removal effectiveness clearly indicates pass through of toxic metals will occur unless canmaking wastewaters are adequately pretreated.

At BAT the toxic metals chromium and zinc are regulated, in addition to aluminum (see Section X). Aluminum is regulated at BAT because of its potential adverse affects upon receiving waters and to control toxic metals that are not specifically regulated. However, since alum (an aluminum sulfate) is often added at POTW and since aluminum is not usually regulated for pretreatment, standards for manganese and copper (which are alloying constituents in the aluminum strip used in canmaking processes) are substituted for aluminum in the final regulation. Thus, pretreatment standards are established for four metals: chromium, zinc, copper, and manganese.

Pretreatment standards are also established for fluoride and phosphorus since both pass through POTW. POTW remove no fluoride. POTW removal of phosphorus is 10 to 20 percent. The BAT treatment technology removes more than 80 percent of these pollutants (see Table X-2).

As described in Section V, the Agency found fourteen specific toxic organic compounds (collectively referred to as total toxic organics or TTO) in canmaking wastewaters. The Agency considered and analyzed whether these pollutants should be specifically regulated. The removal of toxic organics is about 70 percent by a secondary POTW (Table XII-1, page 358). This clearly indicates that pass through of TTO will occur unless canmaking wastewaters are adequately pretreated. Therefore TTO is regulated.

For PSES and PSNS, the pollutants which interfere with, pass through or prevent sludge utilization for food crops must be removed before discharge to the POTW. The model end-of-pipe treatment technologies for PSES and PSNS are the same as those for BAT and NSPS (see Figures X-2 and XI-1) and were selected for the same reasons. The model treatment technology includes removal of TTO-containing oil and grease by oil skimming, chemical emulsion breaking, dissolved air flotation, or a combination of these technologies; chromium reduction where necessary; and removal of toxic metals and other pollutants by lime and settle treatment technology.

The proposed PSES and PSNS were based upon reductions in flow to reduce the total mass of regulated pollutants discharged. Flow reduction is retained in the final regulation. The PSES flow is

83.9 l/1000 cans, which is identical to the BAT flow and which was selected for the same reasons (see Section X). The PSNS flow is 63.6 l/1000 cans, which is identical to the NSPS flow and which was chosen for the same reasons (see Section XI).

Industry Cost and Effluent Reduction of Treatment Options

Proposed and final PSES Options 0, 1, 2, and 3 are parallel to BPT and BAT Options 1, 2, and 3, respectively. Also, proposed and final PSNS Options are parallel to the NSPS Options. Estimates of capital and annual costs for the BAT-PSES option and NSPS-PSNS options were prepared as an aid to choosing the best options. Results for BAT-PSES and NSPS-PSNS are presented in Table X-5.

PSES pollutant reduction benefits were derived from the incremental removal of pollutants beyond raw waste. The pollutant reduction benefits for a "normal plant" were presented in Table X-2. Treatment performance for the indirect dischargers of the subcategory is presented in Table XII-3 (page 360). All pollutant parameter calculations were based on mean raw wastewater concentrations for plants sampled by EPA prior to proposal (Table V-11, page 65). The term "toxic organics" refers to the fourteen toxic organics listed in Table XII-2 (page 359).

Regulated Pollutant Parameters

The Agency reviewed the canmaking wastewater concentrations, the BAT model treatment technology removals, and the POTW removals of major toxic pollutants found in canmaking wastewaters to select the pollutants for regulation. The pollutants to be regulated are the same for the subcategory as were selected for BAT except that (1) TTO or the alternative monitoring parameter, oil and grease is added and (2) standards for managanese and copper are substituted for the proposed standards for aluminum. Toxic metals and toxic organics are regulated to prevent pass through. Conventional pollutants are not regulated because POTW remove these pollutant parameters. Fluoride, phosphorus and manganese are nonconventional pollutant parameters which pass through POTW and are therefore regulated.

As previously discussed, manganese is an alloying constituent in the aluminum strip used in canmaking processes, and its regulation should adequately control all of the toxic metals in canmaking wastewaters and assure the operating effectiveness of the treatment system. The regulation also requires reporting of any change to alloys which results in the use of aluminum alloys in canmaking which contain less than 1.0 percent manganese. This information will enable the Agency to determine whether changes in this regulation are warranted.

PRETREATMENT STANDARDS

Mass based limitations are set forth below (Tables XII-4 and XII-5 pages 361 and 362). The mass based limitations are the only method of designating pretreatment standards since the water use reductions at PSES and PSNS are major features of the treatment and control system. Only mass-based limits will assure the implementation of flow reduction and the consequent reduction of the quantity of pollutants discharged. Therefore, regulation of concentrations alone is not adequate.

The derivation of standards is explained in Section IX. The PSES flow is equal to the BAT flow (83.9 l/1000 cans) and its derivation is presented in Section X. For PSNS, the calculation is the same as NSPS which is presented in Section XI. The PSNS flow, which is equal to the NSPS flow, is 63.6 l/1000 cans.

The effectiveness of the end-of-pipe treatment technology for the removal of regulated pollutants is described in Section VII. Section IX explains the derivations of treatment effectiveness concentrations for chromium, zinc, fluoride, phosphorus, and oil and grease (for alternative monitoring), which were used to establish PSES and PSNS. Sections VII and IX also describe the Combined Metals Data Base (CMDB) and the statistical tests which were used to establish that canmaking wastewaters are comparable to the wastewaters from the categories used to establish the CMDB, and to the wastewaters of plants in other categories used to establish treatment effectiveness. For PSES and PSNS, treatment effectiveness concentrations for manganese and copper were drawn from the CMDB to reflect properly operated lime and settle treatment (see Table VII-21, page 230). For manganese and copper, this transfer of treatment effectiveness data to the canmaking subcategory is appropriate due to the inadequate sampling data from within the subcategory and since canmaking wastewaters have been determined to be comparable to the categories used in the CMDB.

The removal of toxic organic pollutants by oil skimming from coil coating, copper forming and aluminum forming plants is presented in Section VII. Many of the toxic organic pollutants found in canmaking wastewaters are found in coil coating, copper forming or aluminum forming and have been shown to be removed by oil removal. As established in Section VII, the average removal of organics in aluminum forming by oil skimming is about 97 percent. This removal rate is used for projecting the effectiveness of the model oil removal technology in removing TTO in canmaking, because some of the lubricants from aluminum forming are carried on aluminum strip into canmaking operations and because the concentrations of oil in canmaking and aluminum forming are similar (see Section IX for details).

The achievable TTO concentration for PSES and PSNS was derived as the product of this 97 percent removal rate and 2.73 mg/l of TTO, the mean level of the seven toxic organics found prior to proposal in canmaking wastewaters (see Table V-11, page 65). As described in Section V, these mean concentrations were established using three-day composite sampling and analytical techniques conducted in accordance with established EPA sampling protocols. Following proposal, the presence of six of these seven organic pollutants was confirmed and the presence of seven additional toxic organics in treatable amounts was established qualitatively. Following an analysis of this data, the Agency determined that the mean concentration of the fourteen TTO is not expected to exceed 2.73 mg/l in wastewater from a single canmaking plant. The final mean treatment effectiveness concentration for TTO, therefore, is 0.08 mg/l.

Oil removal is the model treatment technology for TTO and is included in the PSES and PSNS control technologies and calculations of corresponding benefits and costs. The Agency believes that good oil and grease removal will allow a plant to meet the total toxic organics limitations. Since monitoring for TTO is costly and requires sophisticated equipment, the Agency is establishing oil and grease as an alternative monitoring parameter for TTO.

The flow reductions required by PSES and PSNS may result in higher concentrations of pollutants in wastewaters prior to end-of-pipe treatment. This issue is discussed in Sections X and XI for BAT and NSPS, respectively, since the model treatment technologies for BAT and NSPS are the same as those for PSES and PSNS.

DEMONSTRATION STATUS

Since the model treatment technologies for PSES and PSNS are the same as BAT and NSPS, respectively, the demonstration status is presented in Sections X and XI.

Table XII-1

POTW REMOVALS OF THE PRIORITY POLLUTANTS FOUND IN CANMAKING WASTEWATER

	Pollutant	Percent Removal by Secondary POTW
11.	1,1,1-Trichloroethane	87
13.	1,1-Dichloroethane	76
15.	1,1,2,2-Tetrachloroethane	89
18.	Bis(2-chloroethyl) ether	Not available
23.	Chloroform	61
29.	1,1-Dichloroethylene	80
44.	Methylene Chloride	58
64.	Pentachlorophenol	52
66.	Bis(2-ethylhexyl) phthalate	62
67.	Butyl benzyl phthalate	59
68.	Di-n-butyl phthalate	48
81.	Phenanthrene	65
85.	Tetrachloroethylene	81
86.	Toluene	90
119.	Chromium	65
120.	Copper	58
124.	Nickel	19
128.	Zinc	65

NOTE: These data compiled from Fate of Priority Pollutants in Publicly Owned Treatment Works, US EPA, EPA No. 440/1-80-301, October, 1980; and Determine National Removal Credits for Selected Pollutants for Publicly Owned Treatment Works, EPA No. 440/82-008, September, 1982.

TABLE XII-2
TOXIC ORGANICS COMPRISING TTO

	Pollutant	Mean Raw Waste At Proposal	Postproposal Data
		(a)	(b)
11.	1,1,1-Trichloroethane	0.561	0.561
13.	1,1,-Dichloroethane		0.018(c)
15.	1,1,2,2-Tetrachloroethane		0.055
18.	Bis (2-chloroethyl) ether		0.066
23.	Chloroform		0.012(d)
29.	1,1-Dichloroethylene	0.093	0.093
44.	Methylene chloride	0.022	0.022
64.	Pentachlorophenol		0.030(d)
66.	Bis (2-ethylhexyl) phthalate	1.55	0.869
67.	Butyl benzyl phthalate	0.022	0.228
68.	Di-n-butyl phthalate	0.464	0.464
81.	Phenanthrene		0.044
85.	Tetrachloroethylene		0.018(d)
86.	Toluene	0.016	0.135
	TOTAL	2.727	2.615

(a) Mean concentrations of toxic organics found above quantifiable limits (>0.010 mg/l) in raw wastewaters sampled by EPA at proposal (See Table V-11).

(b) Mean concentrations of toxic organics including postproposal data.

(c) Toxic organics found above quantifiable limits (>0.010 mg/l) in treated effluent samples analyzed and submitted by Reynolds Aluminum Company (See Table V-21).

(d) Toxic organics found above quantifiable limits (>0.010 mg/l) in treated wastewaters sampled by EPA after proposal (See Table V-19).

TABLE XII-3

POLLUTANT REDUCTION BENEFITS OF CONTROL SYSTEMS - INDIRECT DISCHARGERS

PARAMETER	RAW WASTE	PSES-0		PSES-1	
	kg/yr	Removed kg/yr	Discharged kg/yr	Removed kg/yr	Discharged kg/yr
Flow, 1/10^3 cans			215.0		83.9
Flow, 10^6 1/yr	14052.00		11972.92		4672.22
Chromium	14136.31	13130.58	1005.72	13743.84	392.47
Copper	533.98	0.00	533.98	0.00	533.98
Lead	421.56	0.00	421.56	0.00	421.56
Nickel	2487.20	0.00	2487.20	0.00	2487.20
Zinc	12984.05	9032.99	3951.06	11442.21	1541.83
Aluminum	1.94x10^6	1.92x10^6	26819.34	1.93x10^6	10465.77
Fluoride	235230.48	61623.14	173607.34	167483.29	67747.19
Iron	19630.64	14721.74	4908.90	17715.03	1915.61
Manganese	26010.25	24094.58	1915.67	25262.69	747.56
Phosphorus	85155.12	36305.61	48849.51	66092.46	19062.66
Oil & Grease	92.7x10^6	92.6x10^6	119729.20	92.6x10^6	46722.20
TSS	6.62x10^6	6.47x10^6	143675.04	6.56x10^6	56066.64
TTO	38361.96	37380.18	981.78	37978.84	383.12
Total Toxics	68925.06	59543.75	9381.30	63164.90	5760.16
Total Other	102x10^6	101x10^6	519505.00	101x10^6	202727.63
Total Conventionals	99.3x10^6	99.0x10^6	263404.24	99.2x10^6	102788.84
Sludge			551x106		555x106

TABLE XII-4

PRETREATMENT STANDARDS FOR EXISTING SOURCES
CANMAKING SUBCATEGORY

Pollutant or Pollutant Property	PSES Maximum for any one day		Maximum for monthly average	
	g (lbs)/1000,000 cans manufactured			
*Chromium	36.92	(0.081)	15.10	(0.033)
*Copper	159.41	(0.351)	83.90	(0.185)
Lead	35.24	(0.078)	16.78	(0.037)
Nickel	161.09	(0.355)	106.55	(0.235)
*Zinc	122.49	(0.270)	51.18	(0.113)
Aluminum	539.48	(1.189)	268.48	(0.592)
*Fluoride	4992.05	(11.001)	2214.96	(4.883)
Iron	100.68	(0.222)	51.18	(0.113)
*Manganese	57.05	(0.126)	24.33	(0.054)
*Phosphorus	1401.13	(3.089)	573.04	(1.263)
*Oil & Grease (for alternate monitoring)	1678.00	(3.699)	1006.80	(2.220)
TSS	3439.9	(7.584)	1636.05	(3.607)
*TTO	26.85	(0.059)	12.59	(0.028)

*Regulated Pollutant

TABLE XII-5

PRETREATMENT STANDARDS FOR NEW SOURCES
CANMAKING SUBCATEGORY

Pollutant or Pollutant Property	PSNS Maximum for any one day		PSNS Maximum for monthly average	
	g (lbs)/1,000,000 cans manufactured			
*Chromium	27.98	(0.062)	11.45	(0.025)
*Copper	120.84	(0.266)	63.60	(0.140)
Lead	26.71	(0.059)	12.72	(0.028)
Nickel	122.11	(0.269)	80.77	(0.178)
*Zinc	92.86	(0.205)	38.80	(0.086)
Aluminum	408.95	(0.902)	203.52	(0.449)
*Fluoride	3784.20	(8.343)	1679.04	(3.702)
Iron	76.32	(0.168)	38.80	(0.086)
*Manganese	43.25	(0.095)	18.44	(0.041)
*Phosphorus	1062.12	(2.342)	434.39	(0.958)
*Oil & Grease (for alternate monitoring)	1272.00	(2.804)	763.20	(1.683)
TSS	2607.60	(5.749)	1240.20	(2.734)
*TTO	20.35	(0.045)	9.54	(0.021)

*Regulated Pollutant

SECTION XIII

BEST CONVENTIONAL POLLUTANT CONTROL TECHNOLOGY

The 1977 Amendments added Section 301(b)(2)(E) to the Act establishing "best conventional pollutant control technology" [BAT] for discharges of conventional pollutants from existing industrial point sources. Conventional pollutants are those defined in Section 304(a)(4) [biological oxygen demanding pollutants (BOD-5), total suspended solids (TSS), fecal coliform, and pH], and any additional pollutants defined by the Administrator as "conventional" [oil and grease, 44 FR 44501, July 30, 1979].

BCT is not an additional limitation but replaces BAT for the control of conventional pollutants. In addition to other factors specified in section 304(b)(4)(B), the Act requires that BCT limitations be assessed in light of a two part "cost-reasonableness" test. American Paper Institute v. EPA, 660 F.2d 954 (4th Cir. 1981). The first test compares the cost for private industry to reduce its conventional pollutants with the costs to publicly owned treatment works for similar levels of reduction in their discharge of these pollutants. The second test examines the cost-effectiveness of additional industrial treatment beyond BPT. EPA must find that limitations are "reasonable" under both tests before establishing them as BCT. In no case may BCT be less stringent than BPT.

EPA first published its methodology for carrying out the BCT analysis on August 29, 1979 (44 FR 50732). In the case mentioned above, the Court of Appeals ordered EPA to correct data errors underlying EPA's calculation of the first test, and to apply the second cost test. (EPA had argued that a second cost test was not required.)

EPA has determined that the BAT technology is capable of removing significant amounts of conventional pollutants. However, EPA has not yet promulgated a revised BCT methodology in response to the American Paper Institute v. EPA decision mentioned earlier. EPA is therefore deferring a decision on the appropriate BCT limitations for the canmaking subcategory.

Until the Agency has promulgated BCT limitations for this subcategory, permit writers should incorporate into permits BCT limitations for oil and grease, TSS and pH based upon best professional judgement. Since BCT limitations cannot be less stringent than BPT limitations, permit writers should regard the promulgated BPT limitations as minimum BCT requirements.

SECTION XIV

ACKNOWLEDGMENTS

This document has been prepared by the staff of the Effluent Guidelines Division with assistance from technical contractors, other EPA offices and other persons outside of EPA. This Section is intended to acknowledge the contribution of the persons who have contributed to the development of this report.

The initial effort on this project was carried out by Sverdrup & Parcel and Associates under Contract No. 68-01-4408; Hamilton Standard Division of United Technologies, under Contract No. 68-01-4668, assisted in some sampling and analysis.

The field sampling programs were conducted under the leadership of Garry Aronberg of Sverdrup & Parcel assisted by Donald Washington, Project Manager, Claudia O'Leary, Anthony Tawa, Charles Amelotti, and Jeff Carlton. Hamilton Standard's effort was managed by Daniel J. Lizdas and Robert Blaser and Richard Kearns.

In preparation of this document, the Agency was assisted by Versar Inc., under contract 68-01-6469, and two subcontractors to Versar, Whitescarver Associates, Inc., and JFA, Inc. Versar's effort was managed by Lee McCandless and Pamela Hillis with contributions from Jean Moore and others. John Whitescarver, Robert Hardy, Robert Smith, V. Ramona Wilson, Jon Clarke, and Lisa Taschek of Whitescarver Associates assisted in the preparation of the final development document. JFA's efforts were managed by Geoffrey Grubbs, with substantial assistance from Thomas Wall.

Ellen Siegler of the Office of General Counsel provided legal advice to the project. Josette Bailey was the economic project officer for the project. Henry Kahn and Barnes Johnson provided statistical analysis and assistance for the project. Alexandra Tarnay provided environmental evaluations and word processing was provided by Pearl Smith, Carol Swann, and Glenda Nesby.

Technical direction and supervision of the project was provided by Ernst P. Hall. The technical project officer was Mary L. Belefski, with assistance from V. Ramona Wilson.

Finally, appreciation is expressed to the Can Manufacturers Institute (CMI), the United States Brewers Association (USBA) and the participating can manufacturing companies for their assistance and technical advice.

Preceding page blank

SECTION XV

REFERENCES

1. "The Surface Treatment and Finishing of Aluminum and Its Alloys" by S. Werrick, PhD, Metal Finishing Abstracts, Third Edition, Robert Draper Ltd., Teddington, 1964.

2. Guidebook & Directory, Metal Finishing, 1974, 1975, 1977 and 1978. American Metals and Plastics Publications Inc., One University Plaza Hackensack, New Jersey 90601.

3. The Science of Surface Coatings, edited by Dr. H. W. Chatfield, 1962.

4. Metals Handbook, Volume 2 8th Edition, American Society for Metals, Metals Park, Ohio.

5. Journal of Metal Finishing: "Pretreatment for Water-Borne Coatings" - April, 1977
"Guidelines for Wastewater Treatment" - September, 1977
"Guidelines for Wastewater Treatment" - October, 1977
"Technical Developments in 1977 for Organic (Paint) Coatings, Processes and Equipment" - February, 1978
"Technical Developments in 1977, Inorganic (Metallic) Finishes, Processes and Equipment" - February, 1978
"The Organic Corner" by Joseph Mazia, - April, 1978
"The Organic Corner" by Joseph Mazia, - May, 1978
"The Economical Use of Pretreatment Solutions" - May, 1978
"The Organic Corner" by Joseph Mazia, - June, 1978
"Selection of a Paint Pretreatment System, Part I" - June, 1978
"The Organic Corner," by Joseph Mazia - September, 1978

6. How Do Phosphate Coatings Reduce Wear on Movings Parts, W. R. Cavanagh.

7. Kirk-Othmer Encyclopedia of Chemical Technology, Second Edition, 1963, Interscience Publishers, New York.

8. Encyclopedia of Polymer Science and Technology, Second Edition, 1963, Interscience Publishers, New York.

9. Conversation and written correspondence with the following companies and individuals have been used to develop the data base:

   Parker Company:

Preceding page blank

Mr. Michael Quinn, Mr. Walter Cavanaugh, Mr. James Maurer,
Mr. John Scalise
Division of Oxy Metals Industries
P. O. Box 201
Detroit, MI 45220

Amchem Corporation:
Lester Steinbrecker
Metals Research Division
Brookside Avenue
Ambler, PA 19002

Diamond Shamrock
Metal Coatings Division
P. O. Box 127
Chardon, OH 44024

Wyandotte Chemical:
Mr. Alexander W. Kennedy
Mr. Gary Van Ve Streek
Wyandotte, MI

10. Handbook of Environmental Data on Organic Chemicals, Verschueren, Karel, Van Nostrand Reinhold Co., New York 1977.

11. Handbook of Chemistry, Lange, Norbert, Adolph, McGraw Hill, New York 1973.

12. Dangerous Properties of Industrial Materials, Sax N. Irving, Van Nostrand Reinhold Co. New York.

13. Environmental Control in the Organic and Petrochemical Industries, Jones, H. R, Noyes Data Corp. 1971 .

14. Hazardous Chemicals Handling and Disposal, Howes, Robert and Kent, Robert, Noyes Data Corp., Park Ridge, New Jersey 1970.

15. Industrial Pollution, Sax, N. Irving, Van Nostrand Reinhold Co., New York 1974.

16. "Treatability of 65 Chemicals - Part A - Biochemical Oxidation of Organic Compounds", June 24, 1977, Memorandum, Murray P. Strier to Robert B. Schaffer.

17. "Treatability of Chemicals - Part B - Adsorption of Organic Compounds on Activated Carbon," December 8, 1977, Memorandum, Murray P. Strier to Robert B. Schaffer.

18. "Treatability of the Organic Priority Pollutants - Part C - Their Estimated (30 day avg) Treated Effluents Concentration - A Molecular Engineering Approach", June 1978, Memorandum, Murray P. Strier to Robert B. Schaffer.

19. Water Quality Criteria Second Edition, edited by Jack Edward McKee and Harold W. Wolf, 1963 The Resources Agency of California, State Water Quality Control Board, Publication No. 3-A.

20. The Condensed Chemical Dictionary, Ninth Edition, Revised by Gessner G. Hawley, 1977.

21. Wastewater Treatment Technology, James W. Patterson.

22. Unit Operations for Treatment of Hazardous Industrial Wastes, Edited by D. J. Denyo, 1978.

23. "Development Document For Proposed Existing Source Pretreatment Standards For The Electroplating Point Source Category", February 1978, EPA440/1-78/085.

24. "Industrial Waste and Pretreatment in the Buffalo Municipal System", EPA contract #R803005, Oklahoma, 1977.

25. "Pretreatment of Industrial Wastes", Seminar Handout, U.S. EPA, 1978.

26. "Sources of Metals in Municipal Sludge and Industrial Pretreatment as a Control Option", ORD Task Force on Assessment of Sources of Metals in Sludges and Pretreatment as a Control Option, U.S., EPA 1977.

27. "Effects of Copper on Aerobic Biological Sewage Treatment", Water Pollution Control Federation Journal, February 1963 p 227-241.

28. Wastewater Engineering, 2nd edition, Metcalf and Eddy.

29. Chemical Technology, L.W. Codd, et. al., Barnes and Noble, New York, 1972

30. "Factors Influencing the Condensation of 4-aminoantipyrene with derivatives of Hydroxybenzene - II. Influence of Hydronium Ion Concentration on Absorbtivity," Samuel D. Faust and Edward W. Mikulewicz, Water Research, 1967, Pergannon Press, Great Britain

31. "Factors Influencing the Condensation of 4-aminoantipyrene with derivatives of Hydroxylbenzene - I. a Critique," Samuel

D. Faust and Edward W. Mikulewicz, Water Research, 1967, Pergannon Press, Great Britain

32. Scott, Murray C., "Sulfex™ - A New Process Technology for Removal of Heavy Metals from Waste Streams, " presented at 1977 Purdue Industrial Waste Conference, May 10, 11, and 12, 1977.

33. "Sulfex™ Heavy Metals Waste Treatment Process," Technical Bulletin, Vol. XII, code 4413.2002 (Permutit®) July, 1977.

34. Scott, Murray C., "Treatment of Plating Effluent by Sulfide Process," Products Finishing, August, 1978.

35. Lonouette, Kenneth H., "Heavy Metals Removal," Chemical Engineering, October 17, pp. 73-80.

36. Curry, Nolan A., "Philosophy and Methodology of Metallic Waste Treatment," 27th Industrial Waste Conference.

37. Patterson, James W., Allen, Herbert E. and Scala, John J., "Carbonate Precipitation for Heavy Metals Pollutants," Journal of Water Pollution Control Federation, December, 1977 pp. 2397-2410.

38. Bellack, Ervin, "Arsenic Removal from Potable Water," Journal American Water Works Association, July, 1971.

39. Robinson, A. K. "Sulfide -vs- Hydroxide Precipitation of Heavy Metals from Industrial Wastewater," Presented at EPA/AES First Annual Conference on Advanced Pollution Control for the Metal Finishing Industry, January 17-19, 1978.

40. Sorg, Thomas J., "Treatment Technology to meet the Interim Primary Drinking Water regulations for Inorganics," Journal American Water Works Association, February, 1978, pp. 105-112.

41. Strier, Murray P., "Suggestions for Setting Pretreatment Limits for Heavy Metals and Further Studies of POTW's memorandum to Carl J. Schafer, Office of Quality Review, U.S. E.P.A., April 21, 1977.

42. Rohrer, Kenneth L., "Chemical Precipitants for Lead Bearing Wastewaters," Industrial Water Engineering, June/July, 1975.

43. Jenkins, S. H., Keight, D.G. and Humphreys, R.E., "The Solubilities of Heavy Metal Hydroxides in Water, Sewage and Sewage Sludge-I. The Solubilities of Some Metal

Hydroxides," *International Journal of Air and Water Pollution*, Vol. 8, 1964,pp. 537-556.

44. Bhattacharyya, O., Jumawan, Jr., A.B., and Grieves, R.B., "Separation of Toxic Heavy Metals by Sulfide Precipitation," *Separation Science and Technology*, 14(5), 1979, pp. 441-452.

45. Patterson, James W., "Carbonate Precipitation Treatment for Cadmium and Lead," presented at WWEMA Industrial Pollutant Conference, April 13, 1978.

46. "An Investigation of Techniques for Removal of Cyanide from Electroplating Wastes," Battelle Columbus Laboratories, Industrial Pollution Control Section, November, 1971.

47. Patterson, James W. and Minear, Roger A., "Wastewater Treatment Technology," 2nd edition (State of Illinois, Institute for Environmental Quality) January, 1973.

48. Chamberlin, N.S. and Snyder, Jr., H.B., "Technology of Treating Plating Waste," *10th Industrial Waste Conference*.

49. Hayes, Thomas D. and Theis, Thomas L., "The Distribution of Heavy Metals in Anaerobic Digestion," *Journal of Water Pollution Control Federation*, January, 1978. pp. 61-72.

50. Chen, K.Y., Young, C.S., Jan, T.K. and Rohatgi, N., "Trace Metals in Wastewater Effluent," *Journal of Water Pollution Control Federation*, Vol. 46, No. 12, December, 1974, pp. 2663-2675.

51. Neufeld, Ronald D., Gutierrez, Jorge and Novak, Richard A., A Kinetic Model and Equilibrium Relationship for Metal Accumulation," *Journal of Water Pollution Control Federation*, March, 1977, pp. 489-498.

52. Stover, R.C., Sommers, L.E. and Silviera, D.J., "Evaluation of Metals in Wastewater Sludge," *Journal of Water Pollution Control Federation*, Vol. 48, No. 9, September, 1976, pp. 2165-2175.

53. Neufeld, Howard D. and Hermann, Edward R., "Heavy Metal Removal by Activated Sludge," *Journal of Water Pollution Control Federation*, Vol. 47, No. 2, February, 1975, pp. 310-329.

54. Schroder, Henry A. and Mitchener, Marian, "Toxic Effects of Trace Elements on the Reproduction of Mice and Rats," *Archives of Environmental Health*, Vol. 23, August, 1971, pp. 102-106.

55. Venugopal, B. and Luckey, T.D., "Metal Toxicity in Mammals" (Plenum Press, New York, N.Y.), 1978.

56. Polson, C.J. and Tattergall, R.N., "Clinical Toxicology," (J.B. Lipinocott Company), 1976.

57. Hall, Ernst P. and Barnes, Devereaux, "Treatment of Electroplating Rinse Waters and Effluent Solutions," presented to the American Institute of Chemical Engineers, Miami Beach, Fl., November 12, 1978.

58. Mytelka, Alan I., Czachor, Joseph S., Guggino, William B. and Golub, Howard, "Heavy Metals in Wastewater and Treatment Plant Effluents," Journal of Water Pollution control Federation, Vol. 45, No. 9, September, 1973, pp. 1859-1884.

59. Davis, III, James A., and Jacknow, Joel, "Heavy Metals in Wastewater in Three Urban Areas, "Journal of Water Pollution Control Federation, September, 1975, pp. 2292-2297.

60. Klein, Larry A., Lang, Martin, Nash, Norman and Kirschner, Seymour L., "Sources of Metals in New York City Wastewater," Journal of Water Pollution Control Federation, Vol. 46, No. 12, December, 1974, pp. 2653-2662.

61. Brown, H.G., Hensley, C.P., McKinney, G.L. and Robinson, J.L., "Efficiency of Heavy Metals Removal in Municipal Sewage Treatment Plants," Environmental Letters, 5 (2), 1973, pp. 103-114.

62. Ghosh, Mriganka M. and Zugger, Paul D., "Toxic Effects of Mercury on the Activated Sludge Process," Journal of Water Pollution Control Federation, Vol. 45, No. 3, March, 1973, pp. 424-433.

63. Mowat, Anne, "Measurement of Metal Toxicity by Biochemical Oxygen Demand," Journal of Water Pollution Control Federation, Vol. 48, No. 5, May, 1976, pp. 853-866.

64. Oliver, Barry G. and Cosgrove, Ernest G., "The Efficiency of Heavy Metal Removal by a Conventional Activated Sludge Treatment Plant," Water Research, Vo. 8, 1074, pp. 869-874.

65. "Ambient Water Quality Criteria for Chlorinated Ethanes", PB81-117400, Criteria and Standards Division, Office of Water Regulations and Standards, U.S. EPA.

66. "Ambient Water Quality Criteria for Chloroalkylethers," PB81-117418, Criteria and Standards Division, Office of Water Regulations and Standards, U.S. EPA.

67. "Ambient Water Quality Criteria for Dichloroethylenes," PB81-117525, Criteria and Standards Division, Office of Water Regulations and Standards, U.S. EPA.

68. "Ambient Water Quality Criteria for Halomethanes," PB81-117624, Criteria and Standards Division, Office of Water Regulations and Standards, U.S. EPA.

69. "Ambient Water Quality Criteria for Phthalate Esters," PB81-117780 Criteria and Standards Division, Office of Water Regulations and Standards, U.S. EPA.

70. "Ambient Water Quality Criteria for Toluene", PB81-117855, Criteria and Standards Division, Office of Water Regulations and Standards, U.S. EPA.

71. "Ambient Water Quality Criteria for Arsenic," PB81-117327, Criteria and Standards Division, Office of Water Regulations and Standards, U.S. EPA.

72. "Ambient Water Quality Criteria for Cadmium," PB81-117368, Criteria and Standards Division, Office of Water Regulations and Standards, U.S. EPA.

73. "Ambient Water Quality Criteria for Chromium," PB81-117467, Criteria and Standards Division, Office of Water Regulations and Standards, U.S. EPA.

74. "Ambient Water Quality Criteria for Copper," PB81-117475, Criteria and Standards Division, Office of Water Regulations and Standards, U.S. EPA.

75. "Ambient Water Quality Criteria for Cyanide," PB81-117483, Criteria and Standards Division, Office of Water Regulations and Standards, U.S. EPA.

76. "Ambient Water Quality Criteria for Lead," PB81-117681, Criteria and Standards Division, Office of Water Regulations and Standards, U.S. EPA.

77. "Ambient Water Quality Criteria for Mercury," Criteria and Standards Division, Office of Water Regulations and Standards, U.S. EPA

78. "Ambient Water Quality Criteria for Nickel," PB81-117715, Criteria and Standards Division, Office of Water Regulations and Standards U.S. EPA.

79. "Ambient Water Quality Criteria for Zinc," PB81-117897, Criteria and Standards Division, Office of Water Regulations and Standards, U.S. EPA.

80. Treatability Manual, U.S. Environmental Protection Agency, Office of Research and Development, Washington, D.C. July 1980, EPA - 600/8-80-042a,b,c,d,e.

81. Electroplating Engineering Handbook, edited by H. Kenneth Graham, Van Nostrand Reinhold Company, New York, 1971.

82. Can Manufacturers Institute, "Directory - Cans Manufactured for Sale," 1982.

83. Can Manufacturers Institute, "Metal Can Shipments Report," 1980.

84. Can Manufacturers Institute, "Metal Can Shipments Report," 1981.

85. Church, Fred L. "Can Equipment Sales Ride Wave of Plant Expansions." Modern Metals, April, 1978, pp. 32-40.

86. "Computer Control Increases Productivity, Cuts Downtime at Canmaking plant." The BREWERS DIGEST, July, 1975, pp. 36-38.

87. "Deep-drawn Oval Fish Cans." Iron and Steel Engineer, July, 1974, p. 55.

88. "Design Data." Machine Design, February 14, 1974, pp. 148-150.

89. "Experts Tell What's New in Forming." American Machinist, April 1, 1975, pp. 45-46.

90. "Industry Environmental Activities." The BREWERS DIGEST, August, 1976, p. 14.

91. Knepp, J. E. and L. B. Sargent, Jr. "Lubricants for Drawing and Ironing Aluminum Alloy Beverage Cans." Lubrication Engineering, April, 1978, pp. 196-201.

92. Kuhner, John G. "Pearl's Total Aluminum Can Program." The BREWERS DIGEST, January, 1976, pp. 45-50.

93. "Lone Star Adopts Ultra-Lightweight Seamless Steel Can." The BREWERS DIGEST, May, 1975, pp. 46-47.

94. Lubrication, published by Texaco, Inc. N.Y., N.Y. Volume 61, April-June 1975, pp. 17-18.

95. Lund, H., editor, Industrial Pollution Control Handbook, McGraw-Hill 1971, pp. 612-613.

96. Church, Fred L., "Aluminum's Next Target: Cost-Competative Food Cans," Modern Metals, Vol. 32, May 1976, pp. 81-87.

97. American Society for Metals, Metals Handbook, 8th Edition, 1969, Vol. 4, "Forming."

98. Maeder, Edward G. "The D&I Can: How & Why it Does More With Less Metal." Modern Metals, August, 1975, pp. 55-62.

99. Mastrovich, J. D. "Aluminum Can Manufacture." Lubrication, Vol. 61, April-June, 1975,pp. 17-36.

100. Mathis, Jerry N. "We See a future For Steel Two-Piece Cans.." advertisement, The BREWERS DIGEST, January, 1977, pp. 13.

101. Mungovan, James. "New Can Plant on Target: 2 Million Containers a Day." Modern Metals, Vol. 33, July, 1977, pp. 27-36.

102. "Olympia's Plans for Lone Star." The BREWERS DIGEST, July, 1977, pp. 20-23.

103. "Schmidt's Christens New $7 Million Packaging Facility." Food Engineering, October, 1977, pp. 47-49.

104. Spruance, Frank Palin, Jr. U.S. Patent 2,438,877, September 6, 1945.

105. Sullivan, Barry C. "Lone Star Turns It Around With Returnables, Youth Emphasis." The BREWERS DIGEST, May, 1976, pp. 28-30.

SECTION XVI

GLOSSARY

Accumulation - In reference to biological systems, is the concentration which collects in a tissue or organism which does not disappear with time.

Acidity - The quantitative capacity of aqueous media to react with hydroxyl ions.

Acidulated Rinse - See Sealing Rinse

Act - The Federal Water Pollution Control Act (P.L. 92-500) as amended by the Clean Water Act of 1977 (P.L. 95-217).

Activator - A material that enhances the chemical or physical change when treating the metal surface.

Adsorption - The adhesion of an extremely thin layer of molecules of a gas or liquid to the surface of the solid or liquid with which they are in contact.

Agency - The U.S. Environmental Protection Agency.

Algicide - Chemical used in the control of phytoplankton (algae) in water.

Alkalinity - The quantitative capacity of aqueous media to react with hydrogen ions.

Aluminum Basis Material - Means aluminum and aluminum alloys which are processed in canmaking.

Anionic Surfactant - An ionic type of surface-active substance that has been widely used in cleaning products. The hydrophilic group of these surfactants carries a negative charge in the washing solution.

Anodizing - An electrochemical process of controlled aluminum oxidation producing a hard, transparent oxide up to several mils in thickness.

Area Processed - See Processed Area.

Backwashing - The process of cleaning a filter or ion exchange column by reversing the flow of water.

Baffles - Deflector vanes, guides, grids, gratings, or similar devices constructed or placed in flowing water or sewage to (1) check or effect a more uniform distribution of velocities; (2) absorb energy; (3) divert, guide, or agitate the liquids; or (4) check eddy currents.

Basis Material or Metal - That substance of which the cans are made and that receives the coating and the treatments in preparation of coating.

BAT - The best available technology economically achievable under Section 304(b)(2)(B) of the Act

BCT - The best conventional pollutant control technology, under Section 304(b)(4) of the Act

BDT - The best available demonstrated control technology processes, operating methods, or other alternatives, including where practicable, a standard permitting no discharge of pollutants under Section 306(a)(1) of the Act.

Biochemical Oxygen Demand (BOD) - (1) The quantity of oxygen required for the biological and chemical oxidation of waterborne substances under conditions of test used in the biochemical oxidation of organic matter in a specified time, at a specified temperature, and under specified conditions. (2) Standard test used in assessing wastewater strength.

Biodegradable - The part of organic matter which can be oxidized by bioprocesses, e.g., biodegradable detergents, food wastes, animal manure, etc.

Biological Wastewater Treatment - Forms of wastewater treatment in which bacteria or biochemical action is intensified to stabilize, oxidize, and nitrify the unstable organic matter present.

BMP - Best management practices under Section 304(e) of the Act

Bodymaker - The machine for drawing, or drawing and ironing two-piece can bodies.

BPT - The best practicable control technology currently available under Section 304(b)(1) of the Act.

Buffer - Any of certain combinations of chemicals used to stabilize the pH values or alkalinities of solutions.

Cake - The material resulting from drying or dewatering sludge.

Calibration - The determination, checking, or rectifying of the graduation of any instrument giving quantitative measurements.

Canmaking - The manufacturing operations used to produce various shaped metal containers subsequently used for storing foods, beverages, and other products.

Captive Operation - A manufacturing operation carried out in a facility to support other manufacturing, fabrication, or assembly operations.

Carcinogenic - Referring to the ability of a substance to produce or incite cancer.

Central Treatment Facility - Treatment plant which co-treats process wastewaters from more than one manufacturing operation or cotreats process wastewaters with noncontact cooling water, or with nonprocess wastewaters, miscellaneous runoff, etc.).

Chemical Coagulation - The destabilization and initial aggregation of colloidal and finely divided suspended matter by the addition of a floc-forming chemical. The amount of oxygen expressed in parts per million consumed under specific conditions in the oxidation of the organic and oxidizable inorganic matter contained in an industrial wastewater corrected for the influence of chlorides.

Chemical Oxygen Demand (COD) - (1) A test based on the fact that all organic compounds, with few exceptions, can be oxidized to carbon dioxide and water by the action of strong oxidizing agents under acid conditions. Organic matter is converted to carbon dioxide and water regardless of the biological assimilability of the substances. One of the chief limitations is its ability to differentiate between biologically oxidizable and biologically inert organic matter. The major advantage of this test is the short time required for evaluation (2 hrs). (2) The amount of oxygen required for the chemical oxidation of organics in a liquid.

Chemical Oxidation - A wastewater treatment in which a pollutant is oxidized.

Chemical Precipitation - Precipitation induced by addition of chemicals.

Chlorination - The application of chlorine to water or wastewater generally for the purpose of disinfection, but frequently for accomplishing other biological or chemical results.

Chromate Conversion Coating - A process whereby an aqueous acidified chromate solution consisting mostly of chromic acid and water soluble salts of chromic acid together with various catalysts or activators is applied to the can body.

Chromium Process Controller - A device used to maintain a desirable and constant hexavalent chromium concentration.

Clarification - The removal of suspended solids from wastewater.

Cleaning - The process of removing contaminants from the surface of a coil.

Clean Water Act - The Federal Water Pollution Control Act Amendments of 1972 (33 U.S.C. 1251 et seq.), as amended by the Clean Water Act of 1977 (Public Law 95-217)

Colloids - A finely divided dispersion of one material called the "dispersed phase" (solid) in another material which is called the "dispersion medium" (liquid). Normally negatively charged.

Compatible Pollutant - A specific substance in a waste stream which alone can create a potential pollution problem, yet is used to the advantage of a certain treatment process when combined with other wastes.

Composite - A combination of individual samples of water or wastewater taken at selected intervals and streams and mixed in proportion to flow or time to minimize the effect of the variability of an individual sample.

Concentration Factor - Refers to the biological concentration factor which is the ratio of the concentration within the tissue or organism to the concentration outside the tissue or organism.

Concentration, Hydrogen Ion - The weight of hydrogen ions in grams per liter of solution. Commonly expressed as the pH value that represents the logarithm of the reciprocal of the hydrogen ion concentration.

Contamination - A general term signifying the introduction of microorganisms, chemicals, wastes or sewage which renders the material or solution unfit for its intended use.

Contractor Removal - The disposal of oils, spent solutions, or sludge by means of a scavenger service.

Conversion Coating - The process of applying a chromate, phosphate, complex oxide or other similar protective coating to a metal surface.

Cooling Tower - A device used to cool water used in the manufacturing processes before returning the water for reuse.

Cupping - Process whereby a flat sheet of metal is formed into a cup by means of a die punch operation (a cupper).

Degreasing - The process of removing grease and oil from the surface of the material.

Deionized Water - Water from which dissolved impurities (in the form of free ions) have been removed to reduce its electrical conducting properties and the potential for contamination of the manufacturing process.

Dewatering - A process whereby water is removed from sludge.

Die - Part on a machine that punches shaped holes in, cuts, or forms sheet metal, cardboard, or other stock.

Direct Discharger - A facility which discharges or may discharge pollutants into waters of the United States.

Dissolved Solids - Theoretically the anhydrous residues of the dissolved constituents in water. Actually the term is defined by the method used in determination. In water and wastewater treatment, the Standard Methods tests are used.

Dragout - The solution that adheres to the can and is carried past the edge of the treatment tank.

Drawing - A process where a sheet of metal is pushed into a mold or die by a solid piece of metal (punch), thus flowing over the punch to form a cup.

Draw-redraw - Process in which a second drawing step follows an initial drawing to form a deeper cup.

Drying Beds - Areas for dewatering of sludge by evaporation and seepage.

Dump - The discharge of process waters not usually discharged for maintenance, depletion of chemicals, etc.

Effluent - The wastewaters which are discharged to surface waters, directly or indirectly.

Emergency Procedures - The various special procedures necessary to protect the environment from wastewater treatment plant failures due to power outages, chemical spills, equipment failures, major storms and floods, etc.

Emulsion Breaking - Decreasing the stability of dispersion of one liquid in another.

End-of-Pipe Treatment - The reduction and/or removal of pollutants by chemical treatment just prior to actual discharge.

Equalization - The process whereby waste streams from different sources varying in pH, chemical consitutents, and flow rates are collected in a common container. The effluent stream from this equalization tank will have a fairly constant flow and pH level, and will contain a homogeneous chemical mixture.

Extrusion - Process of shaping by forcing basis material through a die.

Feeder, Chemical - A mechanical device for applying chemicals to water and sewage at a rate controlled manually or automatically by the rate of flow.

Flanging - The forming of a protruding rim or collar on the end of the can body to allow attachment of the end.

Float Gauge - A device for measuring the elevation of the surface of a liquid, the actuating element of which is a buoyant float that rests on the surface of the liquid and rises or falls with it. The elevation of the surface is measured by a chain or tape attached to the float.

Floc - A very fine, fluffy mass formed by the aggregation of fine suspended particles.

Flocculator - An apparatus designed for the formation of floc in water or sewage.

Flocculation - In water and wastewater treatment, the agglomeration of colloidal and finely divided suspended matter after coagulation by gentle stirring by either mechanical or hydraulic means. In biological wastewater treatment where coagulation is not used, agglomeration may be accomplished biologically.

Flow-Proportioned Sample - A sampled stream whose pollutants are apportioned to contributing streams in proportion to the flow rates of the contributing streams.

Grab Sample - A single sample of wastewater taken at neither set time nor flow.

Grease - In wastewater, a group of substances including fats, waxes, free fatty acids, calcium and magnesium soaps, mineral oil, and certain other nonfatty materials. The type of solvent and method used for extraction should be stated for quantification.

Hardness - A characteristic of water, imparted by salts of calcium, magnesium, and iron such as bicarbonates, carbonates, sulfates, chlorides, and nitrates that cause curdling of soap, deposition of scale in boilers, damage in some industrial processes, and sometimes objectionable taste. It may be determined by a standard laboratory procedure or computed from the amounts of calcium and magnesium as well as iron, aluminum, manganese, barium, strontium, and zinc, and is expressed as equivalent calcium carbonate.

Heavy Metals - A general name given to the ions of metallic elements such as copper, zinc, chromium, and nickel.

Holding Tank - A reservoir to contain preparation materials so as to be ready for immediate service.

Indirect Discharger - A facility which introduces or may introduce pollutants into a publicly owned treatment works.

Industrial Wastes - The wastes used directly or indirectly in industrial processes as distinct from domestic or sanitary wastes.

In-Process Control Technology - The regulation and conservation of chemicals and rinse water throughout the operations as opposed to end-of-pipe treatment.

Ion Exchange - A reversible chemical reaction between a solid (ion exchanger) and a fluid (usually a water solution) by means of which ions may be interchanged from one substance to another. The superficial physical structure of the solid is not affected.

Ironing - A process where the side walls of a drawn cup are pressed against the punch, making them thinner and longer, and creating a deeper can of larger volume.

Lagoon - A man-made pond or lake for holding wastewater for the removal of suspended solids. Lagoons are also used as retention ponds.

Landfill - An approved site for dumping of waste solids.

Lime - Any of a family of chemicals consisting essentially of calcium hydroxide made from limestone (calcite).

Limiting Orifice - A device that limits flow by constriction to a relatively small area. A constant flow can be obtained over a wide range of upstream pressures.

Lubricant - A substance such as oil, grease, etc., used for lessening friction.

Make-Up Water - Total amount of water used by process.

Mandrel - A shaft or bar the end of which is inserted into a workpiece to hold it during machining.

Milligrams Per Liter (mg/l) - This is a weight per volume designation used in water and wastewater analysis.

Mutagenic - Referring to the ability of a substance to increase the frequency or extent of mutation.

National Pollutant Discharge Elimination System (NPDES) - The federal mechanism for regulating discharge to surface waters by means of permits. A National Pollutant Discharge Elimination System permit issued under Section 402 of the Act.

Necking - Forming of a narrower portion at the top of a can body.

Neutralization - Chemical addition of either acid or base to a solution such that the pH is adjusted to approximately 7.

Noncontact Cooling Water - Water used for cooling which does not come into direct contact with any raw material, intermediate product, waste product or finished product.

Nonionic Surfactant - A general family of surfactants so called because in solution the entire molecule remains associated. Nonionic molecules orient themselves at surfaces not by an electrical charge, but through separate grease-solubilizing and water-soluble groups within the molecule.

NPDES - National Pollutant Discharge Elimination System.

NSPS - New source performance standards under Section 306 of the Act.

Orthophosphate - An acid or salt containing phosphorus as PO_4.

Outfall - The point or location where sewage or drainage discharges from a sewer, drain, or conduit.

Paint - A liquid composition of plastic resins, pigments and solvents which is converted to a solid film after application as a thin layer by a drying or heat curing process step.

Painted Area - (Expressed in terms of square meters). The dimensional area that receives an enamel, plastic, vinyl, or laminated coating.

Palletizing - The placing of finished cans into a portable storage container prior to their being filled.

Parshall Flume - A calibrated device developed by Parshall for measuring the flow of liquid in an open conduit. It consists essentially of a contracting length, a throat, and an expanding length. At the throat is a sill over which the flow passes as critical depth. The upper and lower heads are each measured at a definite distance from the sill. The lower head cannot be measured unless the sill is submerged more than about 67 percent.

pH - The negative of the logarithm of the hydrogen ion concentration.

pH Adjust - A means of maintaining the optimum pH through the use of chemical additives.

Phosphate Coating - In canmaking the process of forming a conversion coat on aluminum by spraying a hot solution of phosphate containing titanium or zirconium.

Pollutant - The term "pollutant" means dredged spoil, solid wastes, incinerator residue, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials, heat, wrecked or discarded equipment, rock, sand, cellar dirt and industrial, municipal and agricultural waste discharged into water.

Pollutant Parameters - The characteristics or constituents of a waste stream which may alter the chemical, physical, biological, or radiological integrity of water.

Polyelectrolytes - Used as a coagulant or a coagulant aid in water and wastewater treatment. They are synthetic or natural polymers containing ionic constituents. They may be cationic, anionic, or nonionic.

POTW - Publicly Owned Treatment Works.

Prechlorination - (1) Chlorination of water prior to filtration. (2) Chlorination of sewage prior to treatment.

Precipitate - The solid particles formed from a liquid solution due to the saturation of the solid in the solution having been achieved.

Precipitation, Chemical - Precipitation induced by addition of chemicals.

Pretreatment - Any wastewater treatment process used to reduce pollution load partially before the wastewater is introduced into a main sewer system or delivered to a treatment plant for substantial reduction of the pollution load.

Printing - The technique of rolling a design on a painted strip.

Priority Pollutant - The 129 specific pollutants established by the EPA from the 65 pollutants and classes of pollutants as outlined in the consent decree of June 8, 1976.

Process Water - Any water which during manufacturing or processing, comes into direct contact with or results from the production or use of any raw materials, intermediate product, finished product, by-product, or waste product.

PSES - Pretreatment standards for existing sources of indirect discharges under Section 307(b) of the Act.

Publicly Owned Treatment Works (POTW) - A central treatment works serving a municipality.

Raw Wastewater - Plant water prior to any treatment or use.

RCRA - Resource Conservation and Recovery Act (PL 94-580) of 1976, Amendments to Solid Waste Disposal Act.

Recirculated Water - Process water which is returned as process water in the same or in a different process step.

Rectangular Weir - A weir having a notch that is rectangular in shape.

Recycled Water - Process water which is returned to the same process after treatment.

Reduction Practices - (1) Wastewater reduction practices can mean the reduction of water use to lower the volume of wastewater requiring treatment and (2) the use of chemical reduction to lower the valance state of a specific wastewater pollutant.

Reduction - The opposite of oxidation treatment wherein a reductant (chemical) is used to lower the valence state of a pollutant to a less toxic form e.g., the use of SO_2 to "reduce" hexavalent chromium to trivalent chromium in an acidic solution.

Retention Time - The retention time is equal to the volume of a tank divided by the flow rate of liquids into or out of the tank.

Rinse - Water for removal of dragout by dipping, spraying, fogging, etc.

Sanitary Sewer - A sewer that carries water or wastewater from residences, commercial buildings, industrial plants, and institutions together with minor quantities of ground, storm, and surface waters that are not admitted intentionally.

Sealing Rinse - The final rinse in the conversion coating process which contains a slight concentration of chromic acid.

Seaming - In canmaking the joining of two edges of a rolled metal blank to form a cylinder and the joining of ends or tops to can bodies.

Seamless - In canmaking refers to can bodies formed without side seams. Cans are formed by drawing of flat sheet metal into a cupped shape.

Secondary Waste Water Treatment - The treatment of wastewater by biological methods after primary treatment by sedimentation.

Sedimentation - Settling by gravity of matter suspended in water.

Service Water - The water in general use throughout a plant. Usually in canmaking this is a municipal or potable water but it may be specifically treated water in those areas where the readily available water is not suitable for canmaking.

Settleable Solids - (1) That matter in wastewater which will not stay in suspension during a preselected settling period, such as one hour, but either settles to the bottom or floats to the top. (2) In the Imhoff cone test, the volume of matter that settles to the bottom of the cone in one hour.

Skimmer - A device to remove floating matter from wastewaters.

Sludge - The solids (and accompanying water and organic matter) which are separated from sewage or industrial wastewater.

Sludge Dewatering - A process used to increase the solids concentration of sludge.

Sludge Disposal - The final disposal of solid wastes.

Solvent - A liquid capable of dissolving or dispersing one or more other substances.

Spills - A chemical or material spill is an unintentional discharge of more than 10 percent of the daily usage of a regularly used substance. In the case of a rarely used (one per year or less) chemical or substance, a spill is that amount that would result in 10% added loading to the normal air, water or solids waste loadings measured as the closest equivalent pollutant.

Stamping - Forming or cutting of can tops by the application of a die.

Suspended Solids - (1) Solids that either float on the surface of, or are in suspension in water, wastewater, or other liquids, and which are largely removable by laboratory filtering. (2) The quantity of material removed from wastewater in a laboratory test, as prescribed in "Standard Methods for the Examination of Water and Waste Water" and referred to as nonfilterable residue.

Teratogenic - Referring to the ability of a substance to form developmental malformations and monstrosities.

Three-piece cans - Cans formed by combining a cylindrical portion and two ends. Usually, the sides are formed by wrapping a metal around a mandrel and locking the seam.

Total Cyanide - The total content of cyanide including simple and/or complex ions. In analytical terminology, total cyanide is the sum of cyanide amenable to chlorination and that which is not according to standard analytical methods.

Total Solids - The total amount of solids in a wastewater in solution and suspension.

Toxicity - Referring to the ability of a substance to cause injury to an organism through chemical activity.

Treatment Facility Effluent - Treated process wastewater before discharge.

Trimming - Removal of excess metal from the top of a shaped can body.

Turbidity - (1) A condition in water or wastewater caused by the presence of suspended matter, resulting in the scattering and absorption of light rays. (2) A measure of fine suspended matter in liquids. (3) An analytical quantity usually reported in arbitrary turbidity units determined by measurements of light diffraction.

Two-piece cans - Cans formed by drawing a flat metal plate into a cup and attaching a top.

Viscosity - That property of a liquid paint or coating material which describes its ability to resist flow or mixing. Paint viscosity is controlled by solvent additions and its control is essential to effective roller-coater operation and uniform dry films thickness.

Waste plate - Tin plate with defects too severe to repair. It is used for making cans for products such as paint which will not be adversely affected by the defects.

Water Balance - An accounting of all water entering and leaving a unit process or operation in either a liquid or vapor form or via raw material, intermediate product, finished product, by-product, waste product, or via process leaks, so that the difference in flow between all entering and leaving streams is zero.

Water Use - The quantity of process water used in processing a specified number of cans (expressed as l/1,000 cans).

Weir - A diversion dam. (2) A device that has a crest and some containment of known geometric shape, such as a V, trapezoid; or rectangle and is used to measure flow of liquid. The liquid surface is exposed to the atmosphere. Flow is related to upstream height of water above the crest, to position of crest with respect to downstream water surface, and to geometry of the weir opening.

OIL AND GREASE ANALYTICAL METHOD

For determining the concentration of oil and grease in wastewater samples from all subcategories of coil coating, the following methodology which is based on Standard Methods, 15th Edition, Methods 503A and 503E is followed. In this method, a partition gravimetric procedure is used to determine hydrocarbon (petroleum based) oil and grease.

(1) Apparatus
- (i) Separatory funnel, 1 liter, with TFE[1] stopcock.
- (ii) Glass stoppered flask, 125 ml.
- (iii) Distilling flask, 125 ml.
- (iv) Water bath.
- (v) Filter paper, 11 cm diameter.[2]
- (vi) Glass funnel.
- (vii) Magnetic stirrer and Teflon coated stir bar

(2) Reagents
- (i) Hydrochloric acid, HCl, 1 + 1.
- (ii) Trichlorotrifluoroethane[3] (1,1,2-trichloro-1,2,2-trifluoroethane), boiling point 47°C.
  The solvent should leave no measurable residue on evaporation; distill if necessary.
  Do not use any plastic tubing to transfer solvent between containers.
- (iii) Sodium sulfate, Na_2SO_4, anhydrous crystal
- (iv) Silica gel, 60 to 200 mesh[4].
  Dry at 110°C for 24 hours and store in a tightly sealed container.

(3) Procedure

To determine hydrocarbon oil and grease, collect about 1 liter of sample and mark sample level in bottle for later determination of sample volume. Acidify to pH 2 or lower; generally, 5 ml HCl is sufficient. Transfer to a separatory funnel. Carefully rinse sample bottle with 30 ml trichlorotrifluoroethane and add solvent washings to separatory funnel. Preferably shake vigorously for 2 minutes. However, if it is suspected that a stable emulsion will form, shake gently for 5 to 10 minutes. Let layers separate. Drain solvent layer through a funnel containing solvent-moistened filter paper into a tared clean flask. If a clear solvent layer cannot be obtained, add 1 g Na_2SO_4 to the filter paper cone and slowly drain emulsified solvent onto the crystals. Add more Na_2SO_4 if necessary. Extract twice more with 30 ml solvent each but first rinse sample container with each solvent portion. Combine extracts in tared flask and wash filter with an additional 10 to

20 ml solvent. Add 3.0 g silica gel. Stopper flask and stir on a magnetic stirrer for 5 minutes. Filter solution through filter paper and wash silica gel and filter paper with 10 ml solvent and combine with filtrate in tared distilling flask. Distill solvent from distilling flask in a water bath at 70°C. Place flask on a water bath at 70°C for 15 minutes and draw air through it with an applied vacuum for the final 1 minute. Cool in a desiccator for 30 minutes and weigh.

(4) Calculations

Calculation of O&G-E: If the organic solvent is free of residue the gain in weight of the tared distilling flask is due to hydrocarbon oil and grease. Total gain in weight, E, is the amount of hydrocarbon oil and grease in the sample (mg):

$$\text{mg (hydrocarbon oil and grease)/l} = \frac{\text{E} \times 1000}{\text{ml sample}}$$

(5) Use of O&G-E: The value, O&G-E shall be used as the measure of compliance with the oil and grease limitations and standards set forth in this regulation except where total O&G is specifically required.

[1] Teflon® or equivalent
[2] Whatman No. 40 or equivalent
[3] Freon or equivalent
[4] Davidson Grade 950 or equivalent

METRIC UNITS

CONVERSION TABLE

MULTIPLY (ENGLISH UNITS) by TO OBTAIN (METRIC UNITS)

ENGLISH UNIT	ABBREVIATION	CONVERSION	ABBREVIATION	METRIC UNIT
acre	ac	0.405	ha	hectares
acre - feet	ac ft	1233.5	cu m	cubic meters
British Thermal Unit	BTU	0.252	kg cal	kilogram - calories
British Thermal Unit/pound	BTU/lb	0.555	kg cal/kg	kilogram calories/kilogram
cubic feet/minute	cfm	0.028	cu m/min	cubic meters/minute
cubic feet/second	cfs	1.7	cu m/min	cubic meters/minute
cubic feet	cu ft	0.028	cu m	cubic meters
cubic feet	cu ft	28.32	l	liters
cubic inches	cu in	16.39	cu cm	cubic centimeters
degree Fahrenheit	°F	0.555(°F-32)*	°C	degree Centigrade
feet	ft	0.3048	m	meters
gallon	gal	3.785	l	liters
gallon/minute	gpm	0.0631	l/sec	liters/second
horsepower	hp	0.7457	kw	killowatts
inches	in	2.54	cm	centimeters
inches of mercury	in Hg	0.03342	atm	atmospheres
pounds	lb	0.454	kg	kilograms
million gallons/day	mgd	3,785	cu m/day	cubic meters/day
mile	mi	1.609	km	kilometer
pound/square inch (gauge)	psig	(0.06805 psig +1)*	atm	atmospheres (absolute)
square feet	sq ft	0.0929	sq m	square meters
square inches	sq in	6.452	sq cm	square centimeters
ton (short)	ton	0.907	kkg	metric ton (1000 kilogram)
yard	yd	0.9144	m	meter

* Actual conversion, not a multiplier

☆U.S. GOVERNMENT PRINTING OFFICE: 1984 421 545 11805